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MATERIALS FOR THE STUDY OF BUSINESS

PRODUCTION MANAGEMENT

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PRODUCTION MANAGEMENT

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PREFACE

This little volume is an outgrowth of the author's attempts, extending over a period of years, to develop an introductory course in production management which would meet the needs of university students of business. The curricula of collegiate schools of business have tended to develop along functional lines paralleling, in this respect, the customary method of organizing activities within the business enterprise itself. In the development of such programs the functional fields of marketing, accounting, and finance have naturally received more attention than has that of production. Basic training adapted to the needs of students who contemplate entering the production field is of necessity highly technical in character, and for this reason industry has looked to schools of engineering rather than to schools of business for many of its recruits in this field.

In recognition of this opportunity, schools of engineering typically have provided a place for courses in industrial management in their programs. Because of the limited time which can be spared from engineering studies, however, such courses often have been broadly conceived, with the emphasis upon production, but nevertheless dealing somewhat superficially with other functional fields of management upon which schools of business have placed their major emphasis.

On the other hand, the latter, while recognizing that few of their students will probably find employment in the production field, have felt from the beginning that the study of production management should receive some attention if for no other reason than that students of marketing, accounting, or finance, need some acquaintance with production as a means of arriving at a better understanding of their own fields of special interest.

In selecting materials for such studies, however, a plan of organization differing from that ordinarily employed in courses in industrial management as offered in engineering schools has been found desirable. A comprehensive study of the problems of the production executive in the business enterprise is essential, but specific allusions to the problems of marketing, financial, and personnel management may well be

deleted. To attempt to deal with all of these within the confines of a single course must inevitably lay one open to the charge of superficiality, and fortunately is unnecessary when highly specialized studies in each of these fields are provided.

It is the peculiar needs of the business curriculum which the author cites in justification of the plan of organization adhered to in the following pages.

But teachers of management have had their peculiar problems of presentation as well as problems of organization. Realism is essential; and thus the school of business, as well as the law school, has given much thought to what may be called the "problem method" of teaching. The discussion of practical problems of management does bring realism to the classroom; but if relied upon entirely, especially in introductory courses, the method also has its limitations. More often than not, the student with little practical experience lacks the background to derive much benefit from problem discussions. Unless some means is available by which he may acquire this background, he is likely to find difficulty in co-ordinating his studies, and thus fails to secure the comprehensive view of the subject matter which is desired. This background under the circumstances can be gained only by extensive and carefully directed reading. It is the author's experience that, unless such reading is encouraged and insisted upon, the discussion of practical problems in the classroom is at best unsatisfactory to instructor and student.

Accordingly, in presenting these materials an attempt has been made to encourage wide reading and at the same time provide lists of questions and case materials which will test the ability of the student to make practical applications. A given group of problems of the production executive is introduced in each chapter, to be followed by extensive collateral readings suggested in the appended bibliographies. It is expected that the classroom discussions, however, shall be devoted almost altogether to practical problems and concrete cases. The questions, problems, and exercises contained in the Appendix, together with problems of his own choosing which every competent instructor will wish to add, will, it is thought, provide the nucleus around which profitable class discussions may be built. For those desiring additional aids of this nature, references are made in each instance to excellent compilations of case materials already available in published form.

In assembling these materials, extensive reference has been made to many sources. Wherever possible, an attempt has been made to acknowledge these sources in the text. Special acknowledgment is due the author's colleague, J. O. McKinsey, Professor of Business Administration, the School of Commerce and Administration, University of Chicago, and L. P. Alford, Past Vice-President of the American Society of Mechanical Engineers, both of whom made valuable suggestions at the time these studies were being initiated. C. R. Rorem, Ph.D., formerly Associate Professor of Accounting, and B. E. Goetz, Instructor in Accounting, both of the School of Commerce and Administration, University of Chicago, and H. R. Nissley, Associate Professor, Texas Technological College, each read parts of the manuscript and rendered many valuable suggestions and criticisms. To W. H. Spencer, Dean of the School of Commerce and Administration, University of Chicago, the author is indebted for substantial encouragement making possible the publication of the study in its present form. Most of all, no doubt, the author is indebted to the many students who have used these materials through several editions in mimeographed form, and who, by reason of many comments and suggestions, must be credited in some measure for any pedagogical value the book may be found to possess.

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INTRODUCTION

CHAPTER I

ORGANIZED METHOD IN INDUSTRY

The Importance of Method in Manufacturing Operations.—The tendency toward concentration which characterizes modern industry has served to emphasize, as never before, the problems of production management. The ever increasing size of the business unit has inevitably led to more marked differentiation between those who direct and those who actually perform the tasks of industry, thereby demanding new devices and new methods of management.

In the beginning, the introduction of power-driven machinery largely was responsible for these new conditions. The potential energy of a waterfall or of expanding steam seldom can be put to productive use save by means ordinarily beyond the resources of a single individual. To produce and utilize mechanical power economically often requires the co-operative efforts of many workmen. Large groups of workers and enormous investments in equipment have thus been brought together, and the complexities of management have been correspondingly increased.

When the manufacture of a shoe, to use a classic example, was the work of one man who obtained his materials as needed from the neighboring tanner, designed his product largely according to tradition or his own fancy, and fashioned it with simple hand tools which were carried from house to house as he plied his trade, or even after the intricate operation was carried on in his own shop with the aid of other shoemakers, few serious problems of management arose. The efforts of one worker depended very little upon those of other workers. His own skill, rather than the capacity of his tools, determined the product of his labor. There were few problems of co-ordination save the co-ordination of his own movements.

In the modern shoe factory such primitive conditions, obviously enough, do not exist. Intricate machinery of great variety must be secured and installed in the proposed work place before operations may be begun. Power for turning the wheels of these otherwise useless machines must be provided. Large stocks of raw materials must be

The early craftsman's skill consisted chiefly of manual dexterity acquired by long practice. His methods were reduced to simple rules which could readily be transferred from journeyman to apprentice by word of mouth and by example. Many manufacturing operations or processes are inherently no more intricate now than they were in the craftsman's day, but they have of necessity become co-operative enterprises to such a degree that methods of performance must receive much more attention than in former times.

Co-operative enterprise is, of course, not a modern phenomenon. The world contains many mute evidences of material achievements of past ages which could have been wrought only by means of highly organized groups of workers. Little is known of the methods by which many of these results were attained, for historians have usually been more interested in personalities than in methods. But as has been suggested,[1] "the more we study the work of great leaders the more apparent it becomes that these men were also masters of method." The vision and inspiration of great leaders have always been, and doubtless always will be, the chief motivating force in human affairs. Never before has personality commanded such a high premium as in the modern world of business. But the "science of management," if it is to be a science, must base its claims upon ability to develop an organized body of method rather than upon the strong personalities of its leaders.

Industry's Debt to Experience.—The methods responsible for achievements which daily become more amazing are continually being revised to conform with new discoveries and conclusions, and it is well to consider the debt which industry owes in increasing measure to recorded experience. It would be impossible for the modern corporation to exist were it not for the elaborate technique which has been devised by the accountant and statistician for measuring, recording, and interpreting

[1] D. S. Kimball, *Plant Management*, p. 8.

economic activity. The standardization of materials and of methods of manufacture which have contributed so much to the efficiency of production, and the introduction of marvelous mechanical contrivances which display almost human intelligence and more than human precision, would not have been possible except for the painstaking experimentation and meticulous records of many engineers and men of science. The future cannot be anticipated, and plans cannot be made with any degree of certainty, until the experience of the past and of the present has been recorded and interpreted.

The Science of Management.—Careful analysis of experience is the chief characteristic of the "scientific method" which has been responsible for much of man's material progress. This method is just beginning to be applied to problems of management. It has opened the way to progress, but it is too early yet to evaluate its accomplishment in this field of human relationships.

The scientific method may be characterized as an attitude of openmindedness; as a search for truth and a willingness to abandon preconceived notions when new evidence leads to new conclusions; as a desire to measure that which was perhaps known only qualitatively heretofore. Many of the facts common to daily experience are known vaguely, because exact measurement can seldom be achieved without much experimentation and research. It was, for example, probably observed even by primitive man that when water was frozen the resulting ice occupied more space than did the water thus transformed, or that the application of heat to a solid caused it to expand and that it contracted upon being cooled again. Such knowledge was qualitative. It required much careful research and experimentation to measure the phenomena with sufficient accuracy to formulate the laws governing these changes. It is a matter of common observation, to cite another example, that a bar of steel may be stretched, and that, if the tensile force is indefinitely increased, the bar will break. Such generalities, however, have not satisfied the scientist, who by actual test has determined quantitatively the exact nature of these structural changes. He has accumulated evidence which enables him to foresee the exact effect of applying varying loads to a bar of given dimensions and to state with confidence the probable result if the chemical constituents of the metal were to be varied.

It is obviously much more difficult to make exact observations in the

field of management than in the field of metallurgy. Scientific conclusions are less readily formed concerning men than materials. The behavior of a steel bar under given conditions may be predicted with much more confidence than can the behavior of a temperamental workman. But the utility of the guidance thus to be gained in both instances is clear. It is only by such means that plans for the future can be formulated with confidence.

The Separation of Planning and Performance.—The emphasis upon experimentation and research which scientific methods imply has created new problems of organization in the field of production. So long as industrial operations and processes were the product of tradition and time-honored rules, the workman who had gained sufficient knowledge of these to be considered a craftsman could perhaps be trusted to plan, as well as perform, the tasks required of him. Very often, in fact, the same workman designed the product, made all necessary arrangements for the execution of these designs, and actually performed the work in the shop. But when traditions were no longer considered sacred, and it was thought proper to undertake costly investigations to determine both the design and the method of manufacture, it was no longer feasible to assign these responsibilities to the workmen who fashioned the product. Special aptitudes not required of the man in the shop were necessary for these tasks, and it is not strange that progressive managers began to lay stress upon the importance of separating planning and performance. This division of activities occurring first in the designing of the product[1] was quickly seized upon by the pioneers in scientific management, who insisted that it be applied in the planning of the manufacturing operations and the determining of methods as well.[2]

In advocating this, they merely followed the principle of specializa-

[1] As early as 1836, an English writer, Charles Babbage, in a book which indicates that probably he was much in advance of his time, implied that the separation of designing and performance was already common in industry, and stressed the importance of supplying the workman with accurate drawings. (C. Babbage, *Manufactures*, p. 60.)

[2] Frederick Taylor in his first published work insisted that a distinction should be made between the tasks of planning operations and of performance, and suggested that in doing so he was merely advocating the extension of a principle which had been applied by mechanical engineers in the field of design fifty or sixty years before. (F. W. Taylor, "A Piece Rate System," *Transactions of the American Society of Mechanical Engineers*, XVI (1895), 868.) This idea received much more elaborate treatment in his paper, "Shop Management," *ibid.*, Vol. XXIV (1903).

tion to its logical conclusion. Designing, planning of performance, and actual performance were recognized as separate functions each requiring a peculiar type of skill. Responsibility for each aspect of production was accordingly delegated to specialists. The foreman who theretofore had been largely responsible for all these was assigned the task of supervising actual performance. The planning of the product became the task of the engineering department, and the planning of manufacturing operations and the specifying of methods became the responsibility of the production-planning department. This threefold division of activities has been generally accepted by industry and doubtless has contributed to the marked increase in productive efficiency in recent years.

The Contribution of Industrial Research.—Progress either in the field of design or in the quest for better methods of manufacture is dependent upon the laborious accumulation of many scientific data, and in consequence in modern organizations the engineering function often has been greatly expanded to include elaborate agencies of industrial research.

The transition from a "rule of thumb" to a scientific basis in the realm of technology has not been a sudden one. Scientific truths have been discovered and the concrete results of their application often have become apparent only after long periods of study and the accumulation of much experience. One conclusion or discovery has led to another. New principles have been deduced. New applications have been contrived, until eventually manufacturing operations and processes which formerly were very imperfectly understood have come to have a scientific explanation.

The importance of exact scientific knowledge is well illustrated by the history of the iron and steel industry. The peculiar properties of iron ore have been known since ancient times. By placing a quantity of ore among the coals of an open fire man very early discovered that a plastic mass was produced which, upon cooling and refining, possessed qualities which made it highly prized for tool-making purposes. It was soon discovered also that, if this metal and a quantity of charcoal were placed in a sealed pot to which heat was applied for several days or weeks, the resulting material assumed a degree of hardness and strength not formerly possessed. These properties were still further enhanced by careful heating and quenching in water. It was by such crude and little-understood methods that until comparatively recent times steel

was produced. A product of surprising quality was often achieved; but because the processes were based purely upon rule of thumb, control of variations was very ineffective, and the nature of the "heat" was never known until it was completed. It might prove to be of excellent quality. More often than not it was inferior, due to undetected and little-understood variations in the materials used.

It remained for the sciences of physics and chemistry to explain the actual nature of the processes, and it was not until scientific principles were discovered and applied that modern steel-making methods and accurate heat treatments for metals were developed.[1] The steel industry of today is almost altogether the product of scientific research. Steel of uniform quality with properties exactly suited for the use intended are produced and reproduced continually, an impossible feat were it not for the scientific control which the chemist has provided.

But scientific research performs still another function for modern industry besides that of supplying the exact scientific knowledge requisite for control. The effort to lower production costs within the individual business has often led to a quest for new products, for new and improved methods of production, and for means of utilizing more efficiently the residue materials of industry which otherwise might be wasted. This has opened a fruitful field for industrial research which in many instances has produced marvelous results. The search for inventions has been transferred to the laboratory. New developments, which in the past have often depended upon chance observation or contrivance of some inventive genius working alone and with inadequate resources,[2] are usually originated today by scientifically trained research organizations. A need is recognized and the problem is submitted to the research department. Experts analyze the situation; and often, after studies which in many notable instances have carried the investigator far afield in the realm of pure science, a solution is found.

[1] Modern methods of making steel may be said to date from the middle of the last century and are associated with such well-known names in the industry as Bessemer, Siemons, and Martin.

[2] The popular conception of the debt we owe to chance for many of the great inventions which served to herald the Industrial Revolution has perhaps been overemphasized. Recent inquiries have indicated, for example, that in developing the steam engine, Watt and his contemporaries were conversant with all the principles of natural science known to their age, and—what is more important—they used this knowledge and employed the scientific method in making their investigations in a manner which would do credit to the modern scientist

Influence of Industrial Research upon Competition.—In industries in which extensive research is necessary, it is but natural that the influence of this factor upon competition should be important. As Professor Clark aptly says, "Knowledge is the only instrument of production which is not subject to diminishing returns"; for, as he proceeds to explain, considerable expenditures for research may be as essential for the small manufacturer as for the large one, and each increase in output correspondingly lowers the cost of experimentation chargeable to each unit of product.[1]

Industrial research has placed at a distinct disadvantage the small manufacturer, who typically cannot afford costly investments in laboratories.[2] The research facilities and staff of a large organization such as the Eastman Kodak Company, for example, give this organization an enormous competitive advantage which discourages the development of small enterprise in that industry. Wherever the product is of a complex nature peculiarly dependent upon scientific studies, as is true of photographic, electrical, and chemical goods, large organizations tend to dominate the field.

Economics of Mass Production.[3]—The advantage possessed by the large manufacturer in formulating a comprehensive program of industrial research accrues largely from a saving in overhead costs, which is one of the chief economies of mass production. The mechanization of industry, the development of industrial research, and the modern necessity for securing rare executive talents and the costly services of managerial specialists, all have tended to place upon industry an enormous burden of overhead cost which can be borne successfully only when the output is correspondingly great. Mass production seemingly provides the only avenue of escape, and undoubtedly it is the possibility of securing savings in overhead which has prompted many of the mergers and industrial combinations of this modern age.

To be sure, there are other economies of mass production. Some of

[1] J. M. Clark, *The Economics of Overhead Costs*, p. 120.

[2] So great is this disadvantage, in fact, that in many industries apparently the only salvation of the small manufacturer lies in co-operative research. The achievements of the National Electric Light Association afford a notable example of what may be accomplished by this means.

[3] For a comprehensive summary of the economies of mass production the reader is referred to Census Monograph III (1924), *The Integration of Industrial Operation*, by W. L. Thorp, pp. 86–88.

these arise from the very nature of commerce; others are strictly technological in character. Most of the economies of the first type may be completely summarized in the term "superior bargaining power." Large-scale purchasing of raw materials, mass distribution, and large-scale dealings in the labor and money markets usually are attended by important concessions and economies not available to the small manufacturer, who must conduct his operations upon a less extensive scale. These advantages pertain more to the market than to production, however, and, although by no means unimportant in their influence, need not now be considered.[1]

Technological economies of large-scale operations arise chiefly within the production department from two main sources. Those from the first source are related to certain principles of mechanical efficiency and are known as the "economies of large and intricate mechanical units."[2] Those comprising the second group pertain to organization and are known as the "economies of division of labor or specialization."

The relation between mere size and mechanical efficiency in the case of mechanical equipment depends somewhat upon the nature of the tool. Containers, steam boilers, and the cylinder of a steam engine are examples of a large group of tools for which such a relationship exists. To increase the capacity of tools of this sort, other factors remaining constant, their size must be increased. Surface area, weight, and volume are important elements to be considered, volume varying with the cube of the dimensions, area with the square of these dimensions, and weight, which is an approximate measure of the cost of building the machine, usually varying somewhere between because thickness of wall does not usually need to be increased as fast as the other dimensions.[3] With every increment in size, therefore, increased capacity is secured at less cost per unit. This, in a measure at least, explains why power companies who employ equipment principally of this general type have

[1] The effort to improve bargaining power has been the chief justification for many of the industrial mergers of recent years.

[2] J. M. Clark, *op. cit.*, pp. 113–18, presents an interesting and thought-provoking discussion of this particular group of economies.

[3] The principle of mechanics which explains this relationship may in its simplest terms be stated as follows: The resistance of a structural member such as a steel beam or a truss increases faster than its weight, provided, of course, that the force to be resisted is applied at a constant distance from the point of support.

found it desirable, as the demand for their services increases, to replace small units by larger and larger units.[1]

It is a mistake, however, to assert without qualification that "the larger the size of the tool, the smaller will be its cost per unit of capacity,"[2] particularly since for many tools capacity is not a function of size but of speed of operation. The capacity of a sewing machine, an engine lathe, a loom, or a printing press, for example, cannot be increased by building a larger machine but rather by speeding up the mechanism. Increased speed of operation, however, necessarily involves a much more carefully fashioned machine—more accurate fitting of moving parts, superior materials, more elaborate lubricating mechanism—and the economic limits of speed are soon reached. Substantial increase in capacity in such instances often is not to be secured by contriving a more costly mechanism but by multiplying the number of units.

Nevertheless, even here some economies may be gained by large-scale operations. Two or more looms, for example, may be tended by one operator as well as may a single unit, and a saving in labor is thereby achieved. Frequently, also, the machine-designer has conceived the idea of integrating a number of machines employed in performing a series of manufacturing operations into a single mechanism which is semi-automatic in operation and thus requires less attendance.[3] Very often, however, such mechanisms are costly and can be used economically only by a manufacturer with considerable resources and sufficient demand for his product to enable him to keep the machine continuously employed.[4]

[1] In substituting one large unit for several small ones, certain sacrifices in flexibility of operation often are incurred. In a power plant, for example, adjustment to varying demand and provision of reserve capacity to be used in case of emergency may be secured much more efficiently under normal conditions by providing a number of smaller units rather than a single large one, even though under ideal operating conditions the latter would be much more efficient.

[2] L. Kotany, "A Theory of Profit and Interest," *Quarterly Journal of Economics*, XXXVI, 432, seems to imply that this statement is universally true, which is, of course, by no means the case.

[3] In the plant of a certain large watch manufacturer, for example, a machine has been designed and built at a reported cost of over a quarter-million dollars which performs over a hundred distinct operations and has supplanted several scores of workers. For obvious reasons such a machine could not be employed by a small watchmaker.

[4] Sufficient demand to enable a tool to be operated to the limit of its capacity may or may not be a necessary condition for the economic use of an automatic tool. If the savings to be derived from its use are large, it will pay to use it even if there is not enough business

Specialization in Manufacturing Operations.—Large-scale production usually is accompanied by a high degree of specialization or division of labor in manufacturing operations. The influence of division of labor upon the acquisition of skill which so greatly impressed Adam Smith a century and a half ago[1] was perhaps never more concretely illustrated than by a statement contained in a letter from Simeon North, then superintendent of the government arsenal at Springfield, Massachusetts, to the Secretary of the Navy in 1808, in which it was explained that "by confining a laborer to a single limb of a pistol until he has made 2,000 I save one fourth of his labor."[2] He might have stated also that the system of organization he had devised resulted in economy of skill as well as economy of labor, since the simplification of tasks which specialization entails makes it possible to assign each workman a task exactly commensurate with his potential abilities, thereby avoiding waste of potential talents and shortening the period of training necessary to secure proficiency of performance.[3]

Extreme specialization obviously may be employed only where many similar units of product are to be manufactured; and it is not by accident that one of the earliest instances on record of the application of such methods in American industry should have been in the manufacture of firearms in governmental arsenals, where large output was required. The application of the principle, however, has been greatly extended since Simeon North's day, until in the modern arsenal even "the limb of a pistol" is the product of many workers. A hundred or so machine-operators are today required to fashion a shoe which formerly would have been made by a single workman. A small army is employed today in assembling an automobile, performing, though in much less time, the same tasks that were performed by a mere handful of work-

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to keep it busy all the time or even a large fraction of the time. Many such machines result in relatively slight savings, however, and then it generally will not pay to use the machine unless it can be worked very nearly up to its full capacity.

[1] Adam Smith in his *Wealth of Nations* attributed these savings to three main sources: (1) the gain in dexterity by the worker; (2) the saving in time in passing from one task to another; and (3) the encouragement lent by specialization to the invention of machines and labor-saving devices.

[2] S. N. D. North and R. H. North, *Memoirs of Simeon North*, p. 83.

[3] This particular saving which seems not to have impressed Adam Smith was stressed by Charles Babbage, *op. cit.*, p. 36. More recent writers have made much of this economy See especially, J. R. Commons, "Labor Conditions in the Meat Packing Industry," *Quarterly Journal of Economics*, Vol. XIX.

men twenty years ago when this modern product was in the "machine-shop stage of development."

Interchangeability.—The full fruits of specialization in manual operations can be secured only when the task assigned to each workman is a repetitive one to be performed over and over again in exactly the same manner. Before such methods may be applied in the manufacture of a complicated assembly product, each part must be completely standardized. For early examples of this phase of standardization, commonly known as "interchangeability of parts," we may again turn to the production of firearms in early American arsenals, where, according to an English traveler in 1809, there was "such exactitude in the finishing of every part of any musket that it was adapted to all parts of any other."[1] Interchangeability has resulted in great savings in the modern factory, particularly in the assembly departments. It has added greatly to the convenience of the user of the product because of the ease with which broken parts may be replaced, and incidentally has in many instances presented new problems to the manufacturer because of increased necessity for accurate workmanship.

The Necessity for Accurate Workmanship.—This increased demand for accuracy in manufacturing operations deserves special mention. Standard parts are ordinarily produced for stock in the modern industrial plant; and the assembling operation is performed in separate departments, sometimes in branch plants located near the market hundreds of miles away. Accurate measurements were not so important in earlier days, when the product was assembled in the shop where minor defects could be corrected as the operation proceeded; but delays of this nature cannot be tolerated where mass-production methods are employed. This new demand for accuracy has centered attention upon the development of instruments of precise measurement, and in no other direction has machine design made such rapid progress during the last twenty years. Frequent inspections of the product during manufacture have become necessary as a means of assuring perfect physical co-ordination when the assembling operation is undertaken. Most significant of all, perhaps, the need for accuracy has made it impossible to rely solely upon the individual skill of the workman who manufactures the product in the shop.

New Uses for the Machine.—These comparatively recent develop-

[1] V. S. Clark, *History of Manufactures*, I, 420.

ments in industrial technique have suggested new uses for the machine. It has often been contended that the introduction of machinery was responsible for these new methods, but it can perhaps be argued with equal force that recognition of the advantages of introducing these methods has often prompted the invention of new machines.[1] To specialization itself may be given much of the credit for mechanical progress. The machine is in one sense always a specialist. It can operate only in rigid cycles; and when adjusted for a given task, even the most complicated mechanical contrivance is limited to comparatively simple repetitive operations. The introduction of machinery has often been preceded by a division of labor corresponding to subsequent mechanical subdivisions of the manufacturing process. Mere chance alone does not explain, for instance, why many of the great inventions of the so-called "heroic age of the Industrial Revolution" originated in England. The industries of that country were in many instances already well organized. The successive stages of manufacture were already differentiated. Already labor was specialized, rendering it a comparatively simple matter to analyze the process into elementary operations which machines could perform.[2]

The Transfer of Skill.—The extension of the principle of interchangeability and the increased importance of accuracy which it entails has still further extended the sphere of the machine simply because few workers are available with the skill required to fashion an accurate product. This has led to the development of "transfer-of-skill" machines. A transfer of skill is made to a tool when the operation to be performed can be accomplished by the aid of the tool with less skill on the part of the operator than if he performed the task unaided by the tool.[3]

In the manufacture of an automobile, for example, the required tolerances in certain working parts, such as crankshafts and ball bearings, sometimes are as high as one ten-thousandth of an inch. To fashion metal parts so accurately is a feat which would require the most skilful workman and infinite pains if the operation were to be performed by hand. But by the aid of machine tools to which the skilled toolmaker has transferred his skill, even these severe limits may be ob-

[1] See *Memoirs of Professor Denison Olmstead* as quoted by J. L. Bishop in *History of American Manufacturing*, I, 517, n.

[2] V. S. Clark, *op. cit.*, I, 419.

[3] D. S. Kimball, *Principles of Industrial Organization* (1925 ed.), pp. 10–13.

served by machine-tenders possessing relatively little skill. Mass production and standardized accuracy would be an impossibility without the aid of such devices.

Sometimes the transfer extends to mental as well as manual skill, as in automatic gear- and screw-cutting machines, the monotype machine, or the Jacquard loom. In such machines no demands are made upon the operator save to keep the tool supplied with material. Transfer of skill is not a new principle in machine design, for it is in some measure common to all tools. But with the introduction of the methods which characterize modern industry, it has been necessary more and more to substitute the skill and accuracy of the machine for that of the workman.

The Necessity for Co-ordination.—The problems raised by these new conditions in industry are not, however, confined to the field of mechanics. For management, the most serious problem, as has already been mentioned, is that of co-ordination. Division of labor, or more properly "specialization," has enormously increased individual productiveness; but unless these individuals are organized and their efforts co-ordinated, the collective result of their labors amounts to nothing. A thousand or more operations performed by as many workmen may be required to produce a single automobile. Each operation is important, but only in its relation to other operations. The ultimate test of the efficiency of each of these operations is the utility of the finished product. Unless the components of that product are physically co-ordinated, and unless they can be brought together at the proper time, no useful results are achieved. Insuring this co-ordination, both physically and in point of time, is an important aim of management.

Co-ordinating Devices in the Modern Organization.—This necessity common to all organizations is reflected in many of the devices of management with which we will be concerned in subsequent chapters. A suggestive list of such "co-ordinating devices" follows:

A. *Organization devices:* Departments or *organization units* which function primarily by insuring unity of action by other departments or organization units:
   1. For the enterprise as a whole:
      a) The department of "control"
         —in the sphere of standards of procedure and records
      b) The personnel department
         —in the sphere of personnel relations
      c) Inter-departmental committees

2. For the production department:
   a) The designing department
      —in the sphere of physical standards
   b) The planning department
      —in the sphere of manufacturing operations
   c) Departmental committees

B. *Procedure devices:* Instructions and records, either formal or informal, which function mainly as means of securing unity of action within the organization:

1. Organization manuals
   —which define the sphere of authority and responsibility of departments and individuals within the organization
2. Orders (not necessarily written orders)
   —which insure that subordinates are informed concerning the plans of those to whom they are responsible
3. Budgets
   —which provide a co-ordinated plan of action or goal
4. Designs, standards, and specifications
   —which insure physical co-ordination of manufacturing processes.

CHAPTER II

THE SPHERE OF PRODUCTION MANAGEMENT

Functionalization within the Business Enterprise.—Progressive developments in business organization and management have always been attended by increased specialization and functional subdivision of responsibility. In the primitive industry of the handicraft stage, and even today in the small shop, all the functions of management may be centered in a single individual. As the size of the business unit increases, the cares and responsibilities soon become too great for one man to bear and a division of responsibility occurs, very likely resulting in a separation between production and distribution activities.[1]

The enterprise continues to prosper, let us assume, and with increased credit requirements a financial department soon makes its appearance. The advantages of centralized purchasing become important, and a purchasing department is organized. Very shortly perhaps, with an ever expanding working force the necessity of unifying policies and methods of dealing with employees gives rise to a personnel department. This continuing process of functionalization sooner or later inevitably raises serious problems of co-ordination, and the controller thus makes his appearance upon the scene, assuming responsibility for record-keeping and providing the means for securing co-ordination of effort throughout the organization. And so it goes. One functional department after another appears as different activities assume importance, until in the modern organization the limiting of the number of major departments clamoring for recognition often has become a real problem.

The Sphere of the Production Manager.—The sphere of the production manager in this group of departmental specialists is fairly easy to determine since it is dependent upon the nature of the manufacturing process. In all such processes, men, materials, and machines must be

[1] It has been suggested that if one were able to study this process of functionalization genetically, one might find that the first divisions occurred very naturally between "inside" activities and "outside" activities, one man, for example, assuming responsibility for the operation of the shop and another assuming responsibility for the sale of the product, thus gradually giving rise to two separate departments: production and sales.

employed; and it is the task of the executive who is responsible for production to determine the proper proportions of these three fundamental factors and to utilize them in the most efficient manner in producing the goods required by the sales department. In accomplishing this result, energy in some form must be applied, and hence power might rightly be regarded as a fourth distinct factor in production were it not for the fact that the source of power is always more or less closely identified with one or another of the three elements already mentioned. Prior to the Industrial Revolution, man-power was the chief source of energy; but with the mechanization of industry, labor has become chiefly the director of energy derived from some other natural source. Even under modern conditions, however, power, whatever may be its source, is applied only through machines which otherwise would be inert and useless. The machine and the energy which drives it thus are so intimately associated that the provision of power may be regarded as merely one aspect of providing the plant itself.

The human factor presents many special problems not encountered in connection with either of the other elements. In acquiring materials, for example, the mutual obligations of buyer and seller are fulfilled when delivery is made and payment is rendered. In the purchase of labor, on the other hand, the laborer must be brought into the plant, and the relationship thus created between employer and employee is much more intimate and often more enduring than that existing between the buyer and seller of commodities. Labor cannot successfully be dealt with simply as a commodity. Training programs, the creation of a wholesome environment, safety provisions, health regulations, and many other humanitarian considerations must be given careful attention if the employer is to receive the full measure of service he has purchased. These humanitarian aspects of labor management constitute an important sector of the subject matter of personnel administration. Unquestionably, such considerations have an important bearing upon the providing and the maintaining of an efficient labor force; but they are not peculiar solely to the production manager's sphere, and may indeed in many cases be entirely removed from his jurisdiction.

The production manager's primary responsibility with respect to labor management is of another sort. Securing and maintaining an efficient labor force is one thing, while utilization of these resources in the most efficient manner is another; and it is for the latter especially

that the production manager must in his sphere assume full responsibility. The efficient utilization of labor presents an engineering problem not unlike that encountered in securing efficient utilization of materials or of plant and equipment, and it is in this sphere that the chief obligation of production management lies.

This distinction between the humanitarian and engineering aspects of labor management is arbitrary, of course, and one which cannot consistently be maintained in practice. Every executive, to be successful, must be skilled in personal administration. Efficient utilization of labor often depends as much upon a keen insight into human nature as upon knowledge of what constitutes a fair day's work. It is a distinction which is convenient for purposes of discussion, however, and one which will be observed in this present study in which the sphere of production management will be regarded as consisting of three things:

1. The control of the plant investment.

2. The control of materials, including raw materials, supplies, goods in process, and finished goods until they are transferred to the jurisdiction of the selling department.

3. The control of operations, which involves the utilizing of plant, labor, and materials in the production of finished goods.

Production Problems Differ in Different Industries.—Production processes in different industries vary as much as do the resulting commodities, and these variations explain wide differences in managerial practices. The relative importance of the three factors, materials, labor, and equipment, is by no means identical in all industries. In some, the cost of materials comprises much of the greater portion of the cost of the finished product. In other, though less frequent, instances, labor costs are disproportionately high. In still others, both material and labor costs are relatively unimportant, and much of the value added by manufacture is attributable to the heavy investment in plant.

When one factor is of exceptional importance in comparison with the other two, it is necessary to lay particular stress upon its control. A simple illustration will serve to emphasize this fact. In a certain plant the material costs normally represent 90 per cent of the cost of the final product, the remaining 10 per cent comprising in equal amounts the costs of labor and equipment. It is evident that if, through mismanagement, material costs should be increased—say 10 per cent—other factors remaining constant, the cost of the finished product would likewise

be increased in almost the same proportion. Because of the slight importance of the other elements, a similar increase in either would result in increasing the cost of the final product a mere one-half of 1 per cent, an amount relatively unimportant.

The significance of this has long been recognized by business managers. In the meat-packing and flour-milling industries, for example, where material costs represent so large a portion of the value of the finished product, great stress is laid upon shrewd buying.[1] In industries where labor costs are disproportionately high, personnel relationships are likely to receive most attention. And in industries where overhead costs are especially important, as in the public utilities, particular efforts are made to regularize output and maintain maximum production as means of securing an economical distribution of this relatively fixed element of cost.[2]

Types of Manufacturing Processes.—Manufacturing processes are of three general types: analytic, synthetic, and conditional.[3] An analytic process is one in which one main raw material is broken down or subdivided, thereby yielding a number of finished products. The packing industry, flour-milling, the coke and gas industry, and most refining industries are illustrations of this general type. A synthetic, or what is often more properly called an "assembling," process is one in which a number of materials are combined, either chemically or mechanically,

[1] J. H. Bliss, *Management through Accounts*, pp. 513–14.

[2] Some interesting examples of industries where this unbalanced condition is particularly important are shown in the following table:

Industry	Percentage of Total Cost Representing the Cost of Each of the Elements		
	Material	Labor	Overhead
Slaughtering and packing	92	5	3
Sugar-refining (cane)	93	4	3
Flour-milling	94	2½	3½
Cotton goods	70	19	11
Lumber	47	48	5
Engraving	36	42	22
Watchmaking	23	61	16
Ice manufacture	18	36	46

These figures are compiled from census returns; and due to the incomplete data avai' able, it is probable that the overhead, which, as shown, includes supervision, rental c plant, taxes, fuel, and power, is considerably understated. An extreme case of heavy ove head not shown above is a hydroelectric plant where practically no direct materials a employed and very little labor is required.

[3] P. F. Walker, *Management Engineering*, p. 23.

to form a new product. The manufacture of soap, paint and varnish, textiles, Portland cement, and all mechanical assembly products, illustrate this kind of process. Conditional processes involve merely a change in the form or condition of a single raw material. Iron-founding, lumbering, ice manufacture, tanning, and brick-making afford illustrations of this kind. Purely conditional processes are ordinarily less complex than either of the other general types.

In analytic industries special problems are often presented by the fact that in securing one product other products are necessarily manufactured for which there may be less demand. In the production of coke by modern methods, gas, ammonium sulphate, and almost innumerable coal-tar products are also produced. In the production of meat, many products of entirely different use and nature are also manufactured. These special conditions not only present many difficult problems of determining the cost of the various products but often lead a manufacturer into many diverse lines of production to eliminate waste.

In industries in which synthetic processes predominate, special difficulties are encountered in providing and combining the various elements which enter the finished product. In some industries such as soap-making, for example, this may consist largely of following some predetermined formula. In others, as in machine-building, elaborate preparations in the form of the manufacture of finished parts must be made before the various elements are finally brought together in the assembly department. This often entails a wide variety of manufacturing operations and presents important problems of inventory control since the investment in processed parts is likely to be great.

Continuous Manufacturing Operations.—Perhaps the most significant distinction from the standpoint of control of operations within the plant is the degree of continuity with which it is practicable to carry on the manufacturing process.[1] In some industries operations are nearly always continuous. In the manufacture of flour, cement, pig iron, or soap, for example, materials invariably follow a given path through the plant. passing from process to process always in the same sequence until they appear in the stockroom as finished goods.

[1] It is to be noted that some writers use the term "continuous process industry" in a very different sense. Duncan, for example, divides all industries into two classes, viz., continuous and assembly. (J. C. Duncan, *Principles of Industrial Management*, chaps. vii, viii, ix.) There is no reason, of course, why the processes of an "assembly" industry may not be carried on continuously, which is all that the term is meant to convey as here used.

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Intermittent Operations.—In other industries, an entirely different situation exists. Many commodities may be manufactured in the same plant, each necessitating special treatment, but may in no case be required in sufficient quantity to justify continuous production. In some machine shops and foundries, for example, many orders are placed in process during a given period. All, perhaps, at some points in the process employ identical machines. Few of these orders are similar in every respect, however, and hence not many follow exactly the same path through the plant. Such operations are said to be "intermittent." The most extreme case of this type is the so-called "special-order plant" where the product designated by each order is of special design. Much more frequently each product is standardized but is required in such small quantities that only an occasional lot need be produced. Practically every order is repeated now and then, but the work in the shop varies widely from day to day.

Large-Scale Production and Continuity of Process.—It is worth noting that the distinction between continuous and intermittent processes is one of degree. The processes of nearly every industry may be carried on by either continuous or intermittent methods. It is true that some products, such as flour and cement, are always produced by continuous-process methods. Their manufacture is unlike that of any other kind of product. Standards of uniformity for these products were very early developed. Specialized machinery which can be used for no other purpose has been designed. They are seldom manufactured in the same plant with other products, and continuous-process operations are necessary or the plant suffers a shutdown.

But these same conditions are continually being created in other lines of manufacture. Machine-shops have always been cited as examples of the intermittent-process type of industry. As is well known, however, when any tool or machine part is required in sufficient quantity to make it possible to produce it continuously, the process is so organized. Specialized machinery is designed for producing that single commodity alone; the task of the worker likewise tends to become specialized; and the entire operation is reduced to a continuous basis in no respect differing from the methods which have long been employed in the milling industry. It is quantity production which has made it possible in such instances so to organize the process.

Advantages of Continuity.—The advantages of continuity of process

are essentially the same as those attributed to specialization, for continuity promotes specialization. More specialized, and hence usually more efficient, machines may be employed. The working force may be more effectively organized since there is less variation in the task assigned to each man. And the control of day-to-day production is simplified because all operations are standardized.

The Tendency To Reduce Intermittent Operations.—Recognition of these advantages has in many instances caused manufacturers to eliminate intermittent processes wherever possible. Since this change is dependent upon large-scale production, the tendency is, as might be expected, most apparent in large plants. The automobile industry affords many notable examples of this shift from an intermittent to a continuous basis. Small automobile plants are still compelled to manufacture many of the parts they use by intermittent methods;[1] but in all plants of large capacity, like those of Ford and General Motors, practically all intermittent operations have been eliminated. Gears, axles, crankshafts, and motor parts have all been standardized, and their production has been placed on a continuous basis.

Continuity of Operations and the Choice of Equipment.—The influence upon machine design of this tendency to organize operations on a continuous basis has been very marked. Repetitive operations promote the introduction of tools of special design. Each machine is employed in making only one kind of product and performs the same operation over and over again. It need not be capable of performing any other operation. If specially designed with no attempt to give it adaptivity or versatility, the utmost of efficiency may be secured.[2]

On the other hand, if operations are of the intermittent or jobbing type, versatility is essential. No machine, under such circumstances, is required continuously for a single product. It is important to keep every machine employed if possible. The more adaptable it is, in the sense that it can perform varied operations with fair efficiency, the less chance there is that it will be idle. In consequence, standard machines which are adjustable to a variety of work are preferred. Such tools may not perform any one operation as efficiently as would a machine of special design, but the desire to keep all equipment fully employed is much more important under the circumstances.

[1] In many instances this difficulty is, of course, avoided by purchasing the part required in limited quantity from some outside source.

[2] P. M. Atkins, *Factory Management*, pp. 48–50.

Continuity and the Worker.—A somewhat similar influence is exerted with respect to the worker. As soon as processes are carried on continuously, the tasks assigned to each worker are inclined to become strictly repetitive in character. The skill required of the individual workman is considerably narrowed in scope. Workmen may be chosen for their adaptability for some particular task and become proficient much more quickly than where a high degree of versatility is required. The operator of a machine tool in a jobbing machine-shop must be able to do a variety of work, and employment is accordingly likely to be limited to skilled machinists. But with the introduction of specialized equipment much skill is transferred to the machine. Any alert worker may readily be trained to do all that is required of him.

The automobile industry presents many illustrations of this kind. During the period of development from which this industry has just recently emerged, intermittent methods of manufacture were common. Even the work of assembling the car was in many early instances necessarily an intermittent operation, and skilled machinists were ordinarily employed in this department. In the modern plant, the work of assembly has been so minutely subdivided that the task of each worker is extremely simple. Little special skill is demanded. Even one unaccustomed to factory work becomes an efficient worker in a short time.

This tendency to impose a dull routine upon the worker has been greatly deplored by some observers.[1] If, indeed, it is to result in converting the craftsman into a mere automaton, if the worker's view of life is to be restricted to the tightening of a certain nut on a machine or the setting of a certain screw, if he is to be robbed of all initiative, such methods may well be questioned. Few gains in productive efficiency would be worth such a price.

Fortunately in practice, such dire predictions have as yet not been fulfilled, in the metal trades at least.[2] The skilled machinist has not been supplanted but has become the tool-maker who fashions the machines which less skilful men may operate as well as he himself. The demand for such machines has been enormously increased, and the work which skilled mechanics formerly performed has been turned over to others who otherwise would be classed as common laborers or helpers. There is no question but that the introduction of continuous-proc-

[1] A. Pound, *The Iron Man in Industry.*

[2] See *Report on American Industrial Progress*, by British Industrial Commission (1927).

ess methods has tended to accentuate monotony; but in being forced to accept a monotonous routine, the worker has made other gains. Shortened hours of labor and increased productiveness, which seemingly have often been made possible by these innovations, undoubtedly go far toward compensating the worker for whatever he may have lost.[1]

The Effect with Respect to Production-planning.—Operations which are performed continuously are more easily controlled than those which are intermittent in character. To understand the full import of this statement, it is necessary, first of all, to be familiar with the task of production-planning. In planning the manufacture of any product, there are several questions to be considered. First, it is necessary to determine *where* the processing is to take place. Various operations are likely to be required, and usually they must follow a given sequence. In making a crankshaft, a bar of steel is forged, turned in a lathe, tempered, straightened and balanced, to mention some of the most important operations involved. Each of these calls for a certain type of machine, and the sequence of these operations cannot be varied. To analyze any product and determine beforehand what operations are required in its manufacture requires an intimate acquaintance with shop processes and comprises a very important aspect of production-planning. This function is usually designated by the term "routing."[2] The second step in the planning process is to determine *when* the several operations are to be performed. The problem here is twofold. First, operations must be timed so that the goods will be completed when required; and second, if machines are used for more than one type of job, these various jobs must be fitted together with a view to employing each machine as steadily as possible. This likewise is an important function of the production-planning department. It is commonly known as "scheduling."

The third production-planning activity is known as the "dispatch-

[1] The industrial worker has many more serious grievances against modern mechanized industry and mass production than that he has been forced to accept a monotonous routine and has been robbed of his skill. With all its claims of efficiency, modern industry is still unable to provide regularity of employment, security for those past middle life, and speedy rehabilitation for those unceremoniously thrown out of work by the introduction of machinery and technological progress. These problems—as old as the Industrial Revolution itself—remain, as ever, unsolved.

[2] Production-planning procedures will be discussed in detail in chapter xv. See also R. H. Landsburgh, *Industrial Management*, pp. 410–63.

ing" function. Orders which will give effect to the wishes of those responsible for routing and scheduling must be issued to the operating departments. A constant check on operations must be maintained; progress must be noted; and orders must be revised and reissued when conditions in the shop make the original orders impossible of performance.

Control of Continuous Operations.—In continuous manufacturing operations, these activities associated with production-planning are greatly simplified. Since all operations are repetitive in character, routing almost ceases to exist. The machines to be employed and the sequence of operations were determined when the plant was laid out and built. Also, since all machines are used continuously on a single product, the necessity for scheduling disappears. And since few orders need be issued, there is no need for a dispatching department.

Under the circumstances, the control of current production is relatively simple. Those in authority determine the rate at which manufacturing shall proceed; and standing orders are issued accordingly, which remain in effect until a change in the rate of production is desired.

Control of Intermittent Operations.—The situation is very different where intermittent or job order methods must be employed. Each production order is sent through the shop separately. Where the orders for any product are to be repeated, routing can, of course, be standardized for that particular job, and thus this function may be relegated to a position of little importance. Not so with scheduling, however, for upon the performance of this function depends the prompt completion of orders and economical utilization of the equipment. Dispatching also is of importance. Many jobs or orders often are in process at the same time in the intermittently operated plant, and the dispatcher is responsible for issuing instructions to those who perform the work.

Conclusion.—In this chapter it has been emphasized that the task of production management is determined largely by the nature of the manufacturing process. The problems of the production executive, and the means he may employ in attempting their solution, often are determined by local conditions. In spite of differences in the industrial setting, however, all production executives have many problems in common. All are required to make important decisions with respect to the provision of adequate plant facilities. All must be held responsible

for the safeguarding of materials intrusted to their care. All must strive to make the most effective utilization of plant, materials, and available human resources in the production of salable goods. Thus the problems of production management, as already suggested, fall naturally into three groups: (*a*) plant provision, (*b*) materials control, and (*c*) operation.

In the chapters which follow, representative problems in each of these groups will be discussed in some detail. It need scarcely be suggested that in the selection of topics for study no attempt has been made to include all of the problems with which every production department must deal. Indeed, many such problems which in certain industries are of great importance may not even be mentioned. Nevertheless, it is felt that the list is sufficiently comprehensive to give a fair representation of the task of the typical production executive.

MANAGEMENT OF PLANT FACILITIES

CHAPTER III

PLANT LOCATION

Plant Location an Important Factor in Industrial Success.—The success of a manufacturing enterprise in a highly competitive industry depends, obviously enough, upon the degree to which it is able to place its goods in the market at a cost comparing favorably with that of competitors. In some respects the results of this competitive struggle provide a true index of the relative managerial abilities of the participants. Given equally available raw materials, equally abundant labor and power resources, and equally favorable transportation facilities for reaching the market, the results are entirely within the control of the respective managements. If one manufacturer's product is inferior to that of competitors, methods of improving it can doubtless be found. If his plant is less efficient, the difficulty can be overcome by proper design. By securing equally able managerial talent, he may perhaps demonstrate equal skill in bargaining for raw materials or selling his product. In none of these respects does one manufacturer possess a natural advantage over competitors.

But, on the other hand, if one plant is more favorably located than others, thereby enabling the manager to reach his market more readily and with less expense, to secure delivery of raw materials for less money, or to recruit more efficient or cheaper labor, he possesses an advantage not easily overcome. When times are good, there may be plenty of business for all; but when demand is declining and competitors are exerting themselves to maintain their sales, the only hope of the poorly located plant lies in superior design or management.

The smaller the plant the more important this natural advantage of superior location is likely to be. The small plant must necessarily look chiefly to the local market for an outlet for its product and to local investors for financial support. It is less self-contained and can exert but slight influence upon its surroundings. The large plant, in contrast, is more widely known, reaches a wider market, and is not dependent upon local banking facilities for credit accommodations should these prove inadequate. Its resources and the size of its pay-roll make it possible

for it to exert a transforming influence upon its environment, which sometimes enables such an enterprise to overcome handicaps with which it might otherwise be burdened.[1]

Localization in Industry.—That manufacturers have long been aware of the advantage of a favorable location is strongly evidenced by the pronounced tendency toward geographical localization in industry. Some industries show marked preference for one locality, some for another. Nearly one-half of our automobiles come from southern Michigan. Chicago produces over one-third of our agricultural implements and prepares nearly as great a proportion of our meat products. Fifty per cent of our ammunition and firearms come from Connecticut. New York manufactures three-fourths of our clothing and one-half of our printers' ink. One-half of the nation's steel is rolled in Pennsylvania and eastern Ohio. Wisconsin makes almost two-thirds of the cheese, manufactures one-tenth of the paper, and tans a similar proportion of the leather. Pennsylvania weaves one-third of our carpets. A similar proportion of our machine tools and two-thirds of our rubber products come from Ohio. Over one-half of our lumber comes from the lower Mississippi Valley and the Pacific Coast states, where an abundance of this resource still remains. Massachusetts makes over one-third of the nation's footwear, produces three times as much linen goods as all other states combined; and in addition one-third of our woolens and one-fourth of our cotton goods are the product of her mills. The Carolinas produce a like proportion of our cotton fabrics; and though Rhode Island is the smallest state in the Union, she ranks fifth in the textile industry, there being more spindles within a thirty-mile radius of Providence than in any other similar area in the New World.[2]

Also, territorial specialization is discernible within these favored regions. Thus there are steel towns, textile and shoe towns, and sawmill towns, all of which seemingly lend truth to the statement that "industry thrives best where it throngs most."[3]

This tendency toward location in certain regions is, of course, not characteristic of all industries in like degree. Nearly all states have important baking and confection-manufacturing industries. Nearly all manufacture some brick and paving materials, some furniture, and

[1] E. D. Jones, *The Administration of Industrial Enterprises*, p. 44.

[2] *United States Census of Manufactures.*

[3] M. Keir, *Manufacturing Industries in America*, p. 61.

some flour. All have printing and stonecutting establishments worth mentioning, and apparently all make their own ice. In the latter industry no state produces as much as 10 per cent of the total product. These industries, almost without exception, are obviously of such a nature that they must in some degree remain decentralized. In the absence of these special characteristics, industries have seemingly gravitated to a few favored localities.

Acquired versus Natural Advantages.—The reasons for this regional localization are sometimes at first not apparent. In many instances, in fact, the original reason for locating an industry in a certain community has long since ceased to be important. If it were being re-established today, its present site might not even be considered; but the enterprise continues to prosper largely because of resources which are the acquisition of many years of sound management. The extensive tanning industry on the Atlantic seaboard in the neighborhood of Philadelphia sprang up in this region long ago because of the tanbark which the eastern slope of the Appalachians supplied in abundance. Grand Rapids probably never would have become an important furniture market had it not been founded in the heart of the Michigan woods. The lower Connecticut valley might never have become famous for firearms and for edged tools had not a superior grade of iron ore been found there in early days. In none of these instances are these reasons important today. The modern tannery is not dependent upon proximity to a supply of tanbark. The furniture factories of Grand Rapids no longer draw their materials from local forests. And the mines of Connecticut have long ceased to be important. But these communities have in the meantime acquired other advantages for these particular industries and there is little likelihood that the necessity for relocating them will ever arise, simply because there is no competitive reason for doing so.

The Influence of Chance.—It is not to be inferred, however, from the pronounced regional localization of industry that the choice of plant sites has invariably or even customarily been determined by a deliberate study of natural and competitive factors. A canvass made several years ago of one hundred leading industries disclosed the fact that in almost all instances the plant had been located in the founder's home town.[1] This does not necessarily mean that the plants considered were badly located. Indeed, it may have been the superior advantages of

[1] J. A. Piquet, *Industrial Management*, June, 1925.

their home towns which led these men to identify themselves with these particular enterprises. It does, however, tend to indicate that mere chance has often been an important factor in industrial location. It is said that the presence of an empty building and a group of enterprising town-"boosters" induced the founder of the rubber industry to locate in Akron, Ohio. Detroit may have been the choice of the pioneers in the automobile industry simply because it was their home town and was already the seat of a thriving, though youthful, gas-engine industry. In either case any one of a dozen towns might have been chosen with equally satisfactory results. Chance may have decreed the original location, but nevertheless it does not explain why they continued to thrive. Had these cities not possessed or subsequently acquired advantages equal to those of other communities, their industrial future would not have been assured.

Relation of Location to Transportation.—The economic location for both railroads and industries, as contended many years ago by Wellington,[1] can be determined only by consideration of all factors affecting delivered-to-customer costs. He emphasized particularly that it is economy of operation, rather than merely economy of original investment, which is the true measure of the desirability of a given site, a fact which is self-evident but which increases the difficulty of arriving at a correct conclusion. A variety of factors are involved in such an analysis, of which the following are perhaps most important:

1. Economy in procuring materials.
2. Economy in marketing the product.
3. Economy in recruiting, training, holding, and compensating labor.
4. Economy in producing or purchasing mechanical power.
5. Economy in financing the enterprise.
6. Special pecuniary inducements such as donations, subsidies, low taxes, and non-interference.

The first two of these, at least, are very closely related to the problem of transportation. It is not the location of raw materials, but the economy of a short haul, which induces plants to locate near a source of supply, just as it also is the saving in transportation costs which causes them to seek a location near the market. Aside from the time element involved, it matters little to a plant whether its materials must be carried a hundred or a thousand miles provided the cost of transporta-

[1] A. M. Wellington, *Economic Theory of Railway Location.*

tion is the same. Likewise, though the service value of a convenient market is apparent, there is little evidence that proximity to the market is an important factor in locating some plants. In locating rolling-mills, brick kilns, and furniture factories, this factor undoubtedly is important, for the transportation of these products is costly. This is not true of plants producing watches, collars, and cutlery, for which transportation charges represent a relatively small proportion of delivered-to-customer cost.

The cost of carriage, the speed of delivery, and the possibility of subjecting the commodity in question to the jostling and delay incidental to a long haul without shrinkage or deterioration, all of which are transportation matters, have exerted a profound influence upon the location of many industries. It is transportation, for example, which has determined that the steel industry should concentrate at the "bulk breaking point" for ore and coal shipments on the southern shores of the great lakes. It is transportation which has given many cities like Chicago and Baltimore special advantages for certain industries. And it is largely transportation again which is inducing many manufacturers to establish branches throughout the country to which the components of their product are shipped for final assembly.

Indeed, if transportation facilities were lacking, these manufacturers could never hope to serve more than the local market. In early days territorial specialization in industry was practically impossible because of inadequate means of transportation. The radius of distribution for any commodity, in inland communities at least, was strictly limited. The necessities of existence were procured locally if at all. Even in the production of iron, which today is the product of one of our most highly localized industries, one community had little advantage over another until transportation was developed. Rich deposits of iron ore were very early found at Salisbury, Connecticut, and Lancaster, Pennsylvania; but in spite of this natural advantage, there was little opportunity for these localities to compete with the iron forges which were established in nearly every colonial settlement.[1] As frontiersmen made their way west of the Alleghenies, access to the industries of the eastern slope was again cut off; and iron forges sprang up in Ohio, in Kentucky, and in Tennessee, to supply the local demand. The ability to produce cheap iron in excess of local needs in communities which have subsequently

[1] M. Keir, *op. cit.*, pp. 97–98.

become centers of the steel industry was of little consequence when marketing channels were lacking. Only with the opening of cheap river traffic and the coming of the railroads did the steel centers of today begin to assume importance.

The cheapening and quickening of transportation tends to accentuate the special advantages of favored communities. Natural barriers are broken down, and a manufacturer is no longer sure that even his local market may not be invaded by some distant competitor who in other respects has a location superior to his own.

The situation is further complicated by the fact that transportation cost is not entirely a function of distance. Preferential rate structures and special privileges to shippers in certain localities have developed as a result of our combined rail and water transportation system and exert an influence not always recognized by one lacking experience in traffic matters. These artificial influences have been of particular significance to our seaboard cities and comprise one important reason why New England can compete on very favorable terms with industrial communities which have sprung up in closer proximity to the sources of raw materials upon which her mills depend.[1]

Proximity to Raw Materials.—The importance of a convenient source of raw materials is, as we have seen, conditioned by the transportation factor. When the nature of a commodity is such that transportation is difficult or expensive, the source of supply has an important bearing on the location of the consuming plant. When the material may be transported without difficulty, proximity to the source of supply is of little importance. Nearness to raw materials apparently is of great significance in the manufacture of Portland cement and wood pulp. The cement plants of the Lehigh Valley and the pulp mills of southern Canada bear evidence of this. But it is seemingly of little importance to the silk mills of New Jersey, the jewelry industry in Attleboro, and the rubber factories of Akron. It apparently is of importance in ore reduction, oil-refining, and lumbering, but not in the production of woolen, cotton, and leather goods. It doubtless has been very important in the growth of the packing industry in Chicago, Kansas City, and Omaha; in the location of salmon canneries on the Columbia River, the beet-sugar industry of Utah and Idaho, and the fruit canneries of

[1] The rate on cotton is not much greater from the lower Mississippi or Houston, Texas, to New England than to the Piedmont of North Carolina, though the former distance is, of course, much the greater, and both draw on the same region for their materials.

California and Maryland, but cannot explain the development of an important milling center at Buffalo.

From these illustrations, which might be multiplied indefinitely, the following conclusions may perhaps be drawn:

1. The source of raw materials is likely to be the controlling factor when materials are bulky and of relatively low value. When materials possess high value and small bulk, other factors are likely to be of more importance.

2. When materials are greatly reduced in bulk or rendered more convenient for shipment by the manufacturing process, the plant is usually found near the source of supply. When neither of these is true, other factors usually predominate.

3. When materials are perishable and the manufacturing process renders them less perishable, it is usually undertaken at the source. When they are non-perishable, this is not so often the case.

Marketing Considerations.—In so far as the market is the ruling factor in plant location, the circumstances are virtually the reverse of those just considered. Manufacturing processes which increase the bulk of the commodity or render it more fragile or more susceptible to spoilage must usually be located near the market. This influence is seen in the location of shoe and furniture factories, machine toolshops, baking and confection industries.

Sometimes it is the adoption of some particular method of distribution which gives the marketing factor special significance. Thus, a few years ago when a silk-hosiery manufacturer who planned on selling direct to the consumer by mail was about to build his plant, the traditional location of the silk industry was ignored, and Indianapolis, near the center of population, was chosen in order to minimize parcel-post charges.

Sometimes it is a highly organized marketing center which gives this factor particular importance. The fact that Boston is regarded as the nation's wool and shoe market and Philadelphia has become the market center for the heavy textile trades doubtless gives these cities important advantages for producers of these goods, though this is, of course, an acquired advantage to which many other factors have contributed.

But, as in the case of the raw-material supply, transportation may be seen in all of these as the underlying influence.

The Labor Supply.—Labor considerations constitute another major

factor in industrial location and manufacturing success. The importance of these in a given industry depends somewhat upon:

1. The ratio of labor cost to total manufacturing cost;
2. The possibility of an industry exerting a telling influence upon its environment;
3. The type of labor the industry requires.

As noted in the last chapter, there are some industries, such as those engaged in producing scientific instruments, tool-making, and in lesser degree the textile industries, in which labor charges represent a very high percentage of total costs. Where this characteristic is important, industries tend to locate near the most favorable labor market. This, more than anything else, is perhaps responsible for the rapid strides made in recent years by the southern textile industry, which enjoys particularly favorable labor conditions, as shown by the following table[1] giving the cost per spindle in northern and southern mills:

	Manufacturing Cost Exclusive of Labor	Labor Cost	Total Cost
South	$24.20	$ 9.07	$33.27
North	26.40	13.60	40.00
Difference	$ 2.20	$ 4.53	$ 6.73

The experience of the southern mill-owners indicates very clearly, however, that a low wage scale is not the only requirement of a satisfactory labor supply. They have been forced to rely upon laborers who were unaccustomed to the discipline of factory work,[2] and have found

[1] Adapted from a table given by H. S. Colburn, "Labor Considerations in Plant Location," *Manufacturing Industries*, April, 1927, p. 261.

[2] Some of these difficulties are indicated by the very high turnover and irregular employment which in some instances have forced the Carolina mills to maintain a surplusage of 20 to 25 per cent of spare help in order to be assured of a full complement of workers. (A. Kohn, *The Cotton Mills of South Carolina*, p. 61.) This has been more than offset, however, by the extremely low wage scale which, according to the following comparison, has been much below that of New England (H. S. Colburn, *op. cit.*):

	Weekly Wages		Working Hours
	Male	Female	
Massachusetts	$38.00	$25.00	48
South	22.00	15.00	55

themselves confronted by the problem of weaning the laborer away from his former irresponsible existence, raising his standard of living, and creating new wants to be satisfied. This has often proved a hopeless task in dealing with men reared in the freedom of the hills; but with the coming of a new generation, difficulties are disappearing, and a specialized and efficient labor force is gradually being created in the new environment.

Sometimes an industry is able to exert enough influence to draw labor from other communities. Lumbering has always been a migratory industry and has depended upon a mobile labor force. The steel mills at Gary, Indiana, were located on a barren waste where no labor supply existed, though the Chicago market was not far away. The very nature of both the lumbering and the steel industries is such that ready access to raw materials is of first importance. Furthermore, since both employ a large percentage of unskilled men, always more mobile than skilled workers, sufficient labor can be drawn from distant communities with comparative ease, where others employing specialized workers would doubtless fail.

For industries requiring skilled workers, even an abundance of cheap labor is not a sufficient inducement. Mere numbers of people do not necessarily make a suitable labor environment. As Diemer points out, nearness to a general labor market often has to give place to nearness to a specialized labor market.[1] This does not mean, of course, that a manufacturer must always locate his plant where others manufacturing the same product are already established. Skilled labor is fairly versatile. A machinist may without great preparation be made to feel equally at home in an automobile plant, a locomotive works, or a ship yard—in any sort of shop, in fact, where machine tools are used. A skilled woodworker who has received his training in the furniture industry may quickly adapt himself to work in a piano or musical-instrument factory, or automobile-body plant. None of these industries are direct competitors, but one may and often has created satisfactory skilled labor conditions for others with the same general labor requirements. The skilled labor market at Cincinnati and the growth of the machine-tool industry is a case in point. In the steamboat period, this was an important repair center which developed a labor force possessing mechanical skill, and there is doubtless some significance in the rise of the

[1] H. Diemer, *Factory Organization and Administration*, p. 77.

new industry with the decline of the old. As the steamboat disappeared, a favorable skilled labor market was created which was turned to good account by the tool-builders who located their plants there.[1] Had Cincinnati's skilled labor possessed greater mobility, she might have lost much of her prestige as a manufacturing center with the passing of the river traffic.

As means of communication and transportation are improved, even skilled labor tends to become more mobile; but materials likewise become more mobile in much greater degree, and the labor factor thus must continue to be regarded by many manufacturers as the most important consideration in determining the location of their plants.

The tendency for one industry to create favorable labor conditions for others of entirely different nature is also seen in connection with the so-called "parasitic industry." One type of labor brings with it another type. Wherever heavy industries employing men exclusively predominate, a surplus of female labor is created which invariably attracts light manufacturing industries to the district. Manufacturers of silks, clothing, and novelties are for this reason often found in the same neighborhood with mining and heavy engineering industries. One important advantage for light industries in these locations is the large home-labor supply. The work is of such a nature that much of it can be performed outside the plant, and home workers provide a safety valve without which these highly seasonal industries could scarcely survive. The low-priced jewelry, neckwear, and fancy-shoe industries depend to large extent upon this labor supply.[2]

The Power Supply.—The need for power affects the location of industry in much the same way as does the need for raw materials. Raw materials can be moved to the manufacturing site if other factors are of sufficient importance to induce the industry to locate at some distance from the source of supply. The decision largely depends upon whether the gains secured by moving the materials will offset the increased cost of transportation.

Mechanical power can, of course, seldom be moved from its source. But when the energy is derived from coal, it is possible to move the

[1] J. W. Roe, *English and American Tool Builders*, p. 267.

[2] According to the Massachusetts Bureau of Statistics, one-half of the people employed in producing wearing apparel, jewelry, silverware, paper goods, sporting goods, and celluloid ware do their work at home. (Labor Bulletin No. 101, *Industrial Home Work in Massachusetts.*)

manufacturing plant to the mine,[1] or the coal to the plant, depending upon which course is the cheaper. Under the circumstances, coal is merely one of the raw materials of the industry, and no problem which has not already been discussed is presented.

It is only when power is to be purchased from a public utility or when energy must be converted into power at the source, as in hydro-electrical plants, that the power factor presents a unique situation. Before the development of electrical transmission, water power had to be taken directly from the axle of the water wheel, a necessity the influence of which is seen even today in the mills which everywhere haunt the banks of New England's streams.

Electrical engineering has done much to remove this limitation. Modern superpower systems, sometimes comprising both steam- and water-power plants extending over a wide area, now often carry electrical energy considerable distances, and thus are gradually breaking down the power-cost differentials which formerly gave some regions distinct advantages over others for the location of industries making great use of industrial power.[2]

That mere abundance of natural power resources is of itself often an insufficient inducement to cause intensive industrial development may perhaps be deduced from the fact that many regions most richly endowed with potential water power still remain undeveloped. Unfortunately, much of this resource lies in regions lacking diversity of raw materials and extensive markets and must, in consequence, await development until either transportation or power transmission become much cheaper than at present.[3]

Financial Consideration.—Of the major influences in plant location, financial considerations are doubtless of least importance, though in former days they probably carried much more weight than now. The accumulation of wealth in the whaling industry is given as one reason

[1] The difficulty of finding an adequate water supply for power-plant purposes in the mining region often prevents this solution of the problem.

[2] Fifty miles is, in many instances, the approximate limit of economic high-tension transmission at the present time, though practical installations greatly in excess of this have been made, and the radius of economic transmission is being rapidly extended.

[3] Something concerning the unequal distribution of available water power is indicated by the following, based on estimates made by the Geological Survey:

New England..................	3 per cent of the nation's available water power
South Atlantic states..........	6 per cent of the amount available
Southwestern states...........	6 per cent of the amount available
Pacific Coast states...........	43 per cent of the amount available

why New Bedford is an important textile town, a suggestion that is given some credibility by the fact that the largest milling industries in that city even today are in the hands of families which originally became wealthy in the older industry, and with its decline sought investment in their home town.[1]

But the corporate form of organization and highly organized money markets have given a degree of mobility to capital which makes the location of the investor of little importance in locating the investment.

There is another type of financial consideration which is, no doubt, in many instances of greater significance. Communities which are desirous of attracting industry have many times resorted to subsidies and favorable treatment which tend to reduce operating costs. Low taxes have been cited as one of the reasons for the rapid growth of the southeastern manufacturing region. Fortunately, this is not the only inducement offered by that locality. If it were, manufacturers could scarcely expect to secure permanent benefit by locating there. Subsidies must of necessity be temporary, and in the long run seldom are sufficient compensation for choosing an otherwise ill-favored location.

The Plant Site.—The selection of the plant site presents a more restricted, though scarcely less important, problem than the choice of the general region in which the industry is to be placed. The influences to be considered in both cases are identical, for it is economy of operation which determines whether a large city, a small town, or a suburb of a large city, provides the best site for a given plant.

For some kinds of plants the large city has many advantages. A diversified labor supply is readily obtained. Superior transportation facilities are within easy reach. The large local market may provide a sufficient outlet for the product, thereby insuring economy in distribution. And it is often possible to find satisfactory housing for the plant if the management does not desire to provide its own building. All of these considerations are particularly important to the small manufacturer. Hence, light manufacturing industries, such as those producing clothing, printing, tobacco, and millinery, in which the small manufacturer can compete successfully, are usually found in the crowded industrial districts of our large cities.[2]

[1] M. T. Copeland, *Cotton Manufacturing Industry in the United States* (1912), p. 30.

[2] The Factory Investigating Commission of the State of New York, in its report of 1913, states that 52.6 per cent of the tobacco manufacture, 52.0 per cent of the flower and feather industry, 58.9 per cent of the fur factories, and 78.4 per cent of the clothing industry in [illegible] buildings where these advantages, as well as the dis-

For most industries, however, these congested neighborhoods are intolerable. High land values, high taxes, and restricted possibilities for expansion all tend to increase operating costs, and constantly force the manufacturer farther and farther into the peripheral areas where cheaper accommodations are to be had. Here he is often able to secure most of the advantages of both the city and the small town, with few of the disadvantages of either. If the industry is large enough to create its own environment, it may even choose a site entirely removed from the city, though by so doing the problem of industrial housing must be dealt with. The Pullman Company was perhaps the first American industry to do this on a large scale, thereby setting an example which has been followed by such well-known organizations as the United States Steel Corporation, the Ford Motor Company, and the Kohler Manufacturing Company, in the industrial communities which have sprung up in proximity to their plants.

The small town as a plant site possesses some advantages but also many disadvantages as compared with urban locations. Land values, taxes, and the cost of living for workers are less; but these considerations are often more than offset by the dearth of satisfactory labor, inadequacy of transportation, and the difficulty of attracting the required managerial talent.

Accessibility of the Plant Site.—In considering the site, the fundamental importance of transportation facilities must again be mentioned. It is accessibility for both materials and workers which, more than anything else, gives the urban location an advantage over the small town. Access to a number of railroads instead of one, access to a belt line connecting all converging rail lines instead of a single trunk line, and access to both rail and water transportation instead of only one of these, make for cheaper and quicker transportation, a fact which must always be of prime importance to an industry so long as transportation charges comprise a considerable part of the cost of doing business.[1]

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advantage of keen and often ignorant competition, are important considerations. With the possible exception of the tobacco industry, in which important technological changes have recently occurred, it is probable that approximately these same percentages still prevail in these industries at the present time.

[1] The high ratio of transportation charges to total costs in manufacturing industries is seldom fully realized. An interesting study of this question as it affects the International Harvester Company was presented by G. F. Whitsett, in the *Harvester World*, January, 1921, pp. 4–5. According to his figures, of the $47.00 which was at that time the cost of a ton of steel, $19.65, or 42 per cent, represented transportation charges. Approximately 30 per cent of the cost of southern pine, f.o.b. Chicago, and 25 per cent of the cost of harvesting machinery can be traced to freight bills.

Plant Location: A Recurring Issue.—The discussion in this chapter of the most important factors in the economic location of manufacturing plants has served, perhaps, to emphasize the complexity of the problem. Upon the choice of location depends in large measure the economy of production operations, but it is by no means the problem of the production department alone. The interests of the sales department, the finance department, the purchasing department, the personnel department, and the traffic department are affected as well. All are capable of making important contributions to a correct solution. In many respects plant location is a marketing problem, and the services of the sales department are required in determining the limits of the market it is proposed to serve and in locating the center of distribution of this market. Financial considerations are important, and the services of financial executives are required in properly evaluating the relative financial inducements of the different possible locations. It is a raw-material problem as well, and the purchasing department is in a position to estimate the relative advantages of the different possible sources of supply. Labor costs are likely to be a ruling factor; and in making a survey of labor resources and determining the advantages of different localities, the experience of the personnel department is invaluable. Pervading all of these, as we have seen, is the factor of transportation requiring the technical services of an expert in traffic. In the final analysis an intelligent conclusion must be based on predictions of operating cost, predictions which scarcely can be made without employing the experience and judgment of the cost accountant and the production executive.

Industry as a whole has not as yet developed a technique for determining the economical location of industrial plants. It is fairly obvious that many enterprises are not ideally located and are, in consequence, continually handicapped by the burden of excessive operating costs. As competition becomes more keen, location becomes more important. The poorly situated plant is thus gradually forced to the wall, or else pockets its losses and relocates where operating costs can be reduced. It is this very practical competitive consideration which is gradually impressing business executives with the importance of making an exhaustive analysis of territorial advantages before building their plants, for location is an ever recurring issue in many industries. Expansion sooner or later usually involves some decentralization, and with de-

centralization and the decision to establish branch plants the problem of location again calls for solution.

Causes of Decentralization.—The tendency toward decentralization and the establishing of branches becomes more apparent as manufacturing companies increase in size. Combinations have rarely resulted in bringing all of the combine's operations together in one large plant, but rather in the establishing and operating of a number of complete plants located in various places. As Diemer has observed:[1]

> It is possible that an era of combination may be followed by just as rational a period of decentralization. There are too many intermediary agencies that raise the cost of production and distribution to make centralization and combination of all factories an economic consideration. There is a legitimate most economic territory, and a corresponding maximum capacity for economic production, that points toward distributed production as an ultimate condition, even with centralized capitalization.

There appear to be four main reasons for the development of decentralized operating organizations, each of which gives rise to a reconsideration of the question of economic plant location:

1. Decentralization sometimes is the result of expansion when there is no desire to enlarge the existing plant because of its uneconomic location. The experience of a certain large shoe-manufacturing company located in a midwestern city affords an illustration of this sort. The original plant, when built many years ago, was well located; but with the growth of the city it has been virtually surrounded by the wholesale district, leaving no room for economical expansion. In consequence, when further facilities were required, a branch was built on a suburban site. The difficulty of securing effective control has been increased, but this is compensated by the operating economies which have been secured in the new location.

2. Decentralized operating units are often the natural result of combinations and mergers which are so characteristic of modern industry. A number of going concerns are brought under one management, as in the Steel Corporation or General Motors, with centralized ownership but decentralized operation, of course, since the plants are already in existence when the combine is formed. In determining what plants shall be taken into the combine, their location and their contribution to

[1] H. Diemer, *op. cit.*, p. 75. See also E. G. Rust, "Centralization versus Decentralization in Management," *Annals of the American Academy of Political and Social Science*, September, 1919, pp. 106–7.

the strategy of the new organization must be considered, though doubtless the decision is usually influenced by numerous other competitive reasons.

3. Sometimes decentralization occurs not because of a desire to utilize some strategic location but because a suitable plant is already available and can be acquired. The facilities of the Nash Motor Corporation obviously provide an example of this kind. This company's operations are decentralized in plants located in Kenosha, Racine, and Milwaukee. There is perhaps no particular virtue in this decentralization from the standpoint of operation, but it may, nevertheless, be justified by the fact that plants of defunct motor manufacturers were to be had in these cities at bargain prices.

4. A fourth reason for decentralized manufacturing organizations is seen in the deliberate choice of a factory site because it offers particular advantages for the process in question. Different processes require different locations if maximum efficiency is to be obtained. Raw materials often can be prepared for further manufacture most economically where these materials are procured. The fabricating of finished parts from these materials may require that this process be undertaken near a good labor market. And the bulky and unwieldy character of the finished product may make it necessary to place the assembling process at the center of distribution. A small manufacturer rarely is able to take advantage of all these diverse conditions, but the large organization usually can, and in consequence decentralized manufacturing operations often develop as an industry increases in size.

Economics of Centralization.—The arguments, however, are not all in favor of decentralization, for there are some very real economies to be secured through centralized operations. These are as follows:

1. Economy of plant investment: As a rule, the larger the plant the more economical the investment in buildings and equipment.

2. Economy of operation: The provision of power, internal transport, and similar manufacturing services becomes cheaper as the volume of operations is increased.

3. Economy of management: Control is more difficult in a decentralized organization and requires a higher standard of managerial ability.

Control in the Branch-House Organization.—The last factor mentioned is doubtless most important of all. It is, in fact, the chief reason why many companies should not attempt to develop a complicated

branch-house organization. With decentralized performance, authority and responsibility must be delegated to the branch manager. A more able executive is thus required than if the branch were but one of several departments in a centralized plant where close relations with superiors could be maintained. Unity is essential, and this requires that control be centralized. The difficulties of the central office organization are increased. Elaborate procedures and effective means of interbranch communication must take the place of the continuous supervision and intimate contacts which the centralized organization makes possible. Decentralized performance thus tends to multiply operating costs and risks.

CHAPTER IV

DESIGN AND CONSTRUCTION OF THE PLANT

Importance of Correct Design.—The design and arrangement of the plant, as well as its location, have an important bearing upon the costs of production. Unlike the location of the plant, however, which may or may not have been dictated solely by production considerations, layout is purely a production problem and hence largely dependent upon the resourcefulness and initiative displayed by production executives. The production manager can seldom exert much influence over the costs of production in so far as these are determined by the prices paid for raw materials or labor. These are dependent upon conditions prevailing in commodity and labor markets which are entirely beyond his control. But he can control the use of materials and labor by preventing waste, avoiding non-productive expenditures, eliminating idleness, and directing efforts into channels which will insure the greatest return for a given outlay. The degree of success achieved in dealing with these problems depends almost altogether upon his own efforts and the nature of his plant facilities.

Plant layout and design are particularly significant because of the size and permanence of the investment which is involved. Large expenditures are required in building construction, and important alterations are very difficult to make after a plant is built. An error in the choice of a single machine or other detail may not be a serious matter, for it usually can be corrected at comparatively little expense. On the other hand, an error in the arrangement of departments and processes or in the design of the buildings often can be corrected only by incurring heavy additional expenditures and the risk of serious interruption of existing operations.

To be sure, this is more likely to be the case in some industries than in others. In the manufacture of flour, sugar, ice, and cement, for example, plant design has been fairly well standardized. The processes are so highly mechanized that the cost of production may virtually be determined when the plant is built. At the other extreme, there are the so-called "loft industries" in which plant layout means little. Few ma-

chines are employed, and these are of small size. The entire plant is comprised of small self-contained work places or production centers which have little relation to one another. Space is the chief requirement. The arrangement is almost wholly determined by the necessities of material storage and the density of workers, which in many cities is limited by the specifications of the factory code. The shape of the floor space is likely to be of no consequence, for an efficient plant in such an industry can be designed in almost any type of building which provides satisfactory housing for workers and machines.

Most industries fall somewhere between these extremes. Wherever division of labor or specialization is employed, operations are closely interrelated, each being influenced by those which immediately precede and by those which follow. The flow of materials from process to process must be carefully considered, for it must be borne in mind that it is the work done at the machines and not the moving of materials about the plant which adds value to the product. Unnecessary material movements due to faulty arrangement of machinery add to the cost of production but yield nothing in return. Lack of system in the organization of processes results in uneconomical use of floor space.[1] Crowded conditions hinder the worker, increase the hazards of manufacture, and retard the flow of work through the plant.

Adaptation to the Process.—As suggested, the nature of the process determines the kind of plant required. A building which has been designed for a textile mill might readily be adapted to the needs of a shoe factory but would not satisfy the requirements of a foundry or forge shop. A cement plant or a steel mill differs in type of construction from a flour mill or a cold-storage plant.

Textile processes require, above all else, good lighting and air conditions and extensive floor areas for the placement of huge batteries of machines. The materials are comparatively light and easily handled. The machines, though complicated, are not of massive construction and cause little vibration in operation. Engineering industries, on the other hand, require unobstructed space and sufficient head room to operate overhead cranes and hoisting equipment. Good lighting and air condi-

[1] A striking illustration of this is presented by the experience of a large automobile manufacturer who, by reorganizing his assembly operations, has been able to triple his output without increasing the floor space allotted to this department. Since the cost of floor space is practically a fixed charge, the gain in the assembling operation secured through improvement of the layout is apparent.

tioning, while desirable, are less important; but solid foundations which will stand the strain and incessant pounding of heavy machines are essential. Some plants, like flour mills, extend upward; while others, such as chemical works, oil refineries, and steel mills, spread out in the horizontal plane, introducing contrasts in the industrial landscape, and each in its way attesting to the need for different types of construction for different processes.

The Approach to the Problem.—The traditional method of factory-planning, and the one which, judging by results, is still followed by many organizations, has been to determine the approximate floor area required, acquire a building or group of buildings meeting this general requirement, and adjust the equipment within the rigid limits of the factory walls thus provided. When the plant is purchased or rented, this method of procedure can scarcely be avoided, though the result is likely to be an uneconomic compromise made necessary by the limitations of the building or buildings already in existence.

A much better method, obviously, would be, first to analyze the process or processes, and then to design the factory buildings to conform with these manufacturing requirements. The correct procedure thus indicated is well described in the following quotation:

> The preparation of a plant layout begins with a detailed analysis of the article to be manufactured. This study is to reveal the component parts, and the necessary manufacturing process for the production of each part. Each process is then studied, to determine what machinery, equipment, crafts, and skills will be required. A single process with its workmen, mechanical equipment, and spaces for stock, is a production center—the ultimate manufacturing unit. The space requirements of such units should be worked out in detail. An assemblage of like or closely connected production centers, handled as a single administrative unit, and embracing not only production centers but supplementary centers for administration, communication, and the like, constitutes a shop. The manufacturing shops, together with special centers for power, general administration, and a variety of service departments, constitute the elements of the plant. These elements must be grouped into buildings and yard areas, arranged in a general plan of layout.
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> The conception of a modern plant, from the point of view of layout, is of a huge machine; slightly adjusted in the process of fitting it into a series of buildings; designed and assembled much as a machine would be; and performing its function (much as a machine), in so far as it works smoothly, as an intimately co-ordinated whole.[1]

[1] E. D. Jones, *The Administration of Industrial Enterprises*, pp. 69–70.

Graphical methods often prove useful in the initial stages of this process of designing a factory layout.[1] Templates each representing a production center are first drawn to scale. These are then laid out on a drawing-board or table and are arranged and rearranged with reference to one another until the most effective combination is found. This arrangement not only will depend upon the number and types of production centers to be included but must also provide adequate space for aisles, temporary storage of goods in process, internal-transport and power-transmission equipment, and service centers such as dispatching cages, tool cribs, restrooms, and toilet facilities.

Until the departments have thus been defined, the form of the building or buildings may scarcely be determined. In planning these, some adjustment of the process layout is often required in order to secure a practical design. It must not be entirely forgotten that buildings are more or less permanent investments, while plant arrangement depends somewhat upon the design of the product which may be changed from time to time.[2] Lack of flexibility in the interior arrangement of the plant is likely to prove a serious defect when such changes must be made.

In plants of large size both economy and flexibility usually are increased by providing a number of buildings rather than a single one of sufficient size to house the entire process. There are practical limitations upon the size of factory buildings. The height of such structures is limited by the fact that, above a certain minimum, construction costs increase very rapidly as the height of the building is increased. The width of factory buildings is definitely limited if natural lighting is to be utilized; and although the length of the building is placed under no such restrictions, the costs of construction are not materially reduced by extending the length of the structure indefinitely. At the same time greater flexibility is assured and hazards are reduced by breaking the plant up into a number of buildings of limited extent. Different processes require different types of construction, and this too is an important factor in determining the number and dimensions of the structures to be provided.

[1] For a comprehensive explanation of this method the reader is referred to P. M. Atkins, *Factory Management*, pp. 110–14.

[2] H. T. Noyes, "Planning for a New Manufacturing Plant," *Annals of American Academy of Political and Social Science*, LXXXV (September, 1919), 69.

The final step in designing the plant layout is the arrangement of the factory buildings in proper relation to one another. This task is not unlike that of arranging production centers and departments within each building, and the following factors require consideration:

1. The insuring of an economical flow of work between processes.
2. The adjustment of the plant to the plant site.
3. Provision for future development without undue interference with existing processes.
4. The choice of interbuilding transport, and the adaptation of building location to these means.
5. The location of manufacturing service departments, including material storerooms and yards, shipping facilities, and power-house.

The arrangement of service facilities is worthy of special emphasis. Many of these services are associated with off-plant movements of materials, finished goods, fuel, or power-house waste, and the transportation aspects of the problem are important. In plants where inbound and outbound freight shipments are of large proportions, this transportation problem may, in fact, become the ruling consideration. The officials of terminal railways in large industrial centers can frequently cite instances where manufacturers are continually incurring transportation delays and heavy switching charges which might have been materially reduced had their plants been properly designed.

Horizontal versus Vertical Construction.—But while the process layout undoubtedly should determine the general design of the plant, the economic limitations of building construction also exert an influence upon the layout. The choice between single- and multiple-story construction, for instance, has an important bearing upon both construction and operating costs. In general, the decision depends upon (1) the relative costs of construction, (2) the value of the plant site, and (3) the relative economies of operation.

A two-story building contains twice as much floor space as one of single-floor construction of the same length and width, but the cost of construction is not usually increased in like proportion. The most important items of building cost are the foundation and the roof. These must be practically the same whether there are one or several floors. There are certain offsetting costs, of course. In multiple-story construction, space must be provided for stairways, ramps, or elevator shafts;

and if the height of the structure is to be greatly increased, much heavier foundations are required. This latter necessity under ordinary circumstances usually becomes an important consideration in buildings of more than three or four stories. It explains why factory buildings are rarely constructed in excess of this height.[1] High land values have the effect of very rapidly increasing the economic height of buildings, but this factor is not important in many industrial districts.

In many instances, including textile, shoe, and light-machine manufacture, multiple-story construction entails few operating handicaps. Processes of this type usually are housed in buildings of three or four stories which provide floor space at minimum cost. In other industries, height is even a distinct operating advantage. Flour-milling is the best example of this type where vertical construction is invariably adopted as a means of utilizing gravity in internal transport. Wheat possesses great liquidity, and when raised to the top of the building readily flows by gravity from machine to machine on its downward path.

There are other industries employing processes which must, in contrast, always be placed on the ground floor. Heavy grinding mills, such as are used in cement manufacture, heavy presses, forge hammers, and metal-cutting machinery, retorts, furnaces, and steel rolling-mills, are all of this character. Usually they require massive foundations which are independent of the building itself, and the cost of these would be prohibitive if the equipment were to be located on the upper floors. Such industries thus invariably seek out low-value sites where the plant may be laid out in the horizontal plane.

Types of Plant Construction.—Manufacturing industries have tended to develop their own distinctive building types. In form and general appearance, bare utility has usually been the ruling consideration, though in some notable instances of modern plant construction aesthetic and architectural values have been successfully realized. Ornate architectural treatment is obviously inappropriate. The design of a factory building should express in a single straightforward manner that it is a factory building, but there need be no conflict between sightliness and efficiency. The factory building, just as the more pretentious hotel,

[1] The economical limit in height for mill construction is usually three floors, though the cost per foot of floor space is not materially altered by adding a fourth floor. With reinforced-concrete construction it is usually found that somewhat greater heights give minimum unit costs, while with steel-frame construction, six floors usually give minimum costs where land values may be disregarded.

retail store, or office building, expresses something of the character of the owner or tenant; and more attention by manufacturers to the outward appearances and the beautifying of their factory grounds would unquestionably go far in removing the ugliness and sordidness so prevalent in American industrial communities. Pleasant surroundings react favorably upon the worker and inspire him with pride in his employment. At the same time they possess considerable advertising value and thus doubtless often yield handsome returns on the relatively slight investment involved.

Some manufacturers, by the very nature of their operations, require highly specialized types of construction. Breweries and cold-storage plants afford examples of this, a fact which has made it very difficult for the former to find economic employment for the facilities which have been rendered useless by the passing of that industry. In other instances, the transitory character of the enterprise has had an influence. Sawmills, for example, have always been temporary in character, and the cheapest possible construction has usually been resorted to in order that little need be sacrificed when the local supply of raw materials upon which the industry depends is exhausted.

In other industries of a more enduring character, permanent construction has nearly always been the rule. The textile industry of New England long ago developed the distinctive type of mill so much in evidence in that region. Huge multiple-story buildings, rectangular and unadorned, with massive brick walls pierced on either side by long rows of windows, have served this and many similar industries well. In the beginning there was little which was unusual about this type of factory building. The outer walls and interior posts supported floors of close wood construction similar to those commonly employed in constructing dwelling-houses today. The risk from fire which construction of this sort necessarily entails is its most serious defect, and has led to the development of an improved type of "mill construction" which, although of wood, is of a slow-burning character and is given very favorable rating by insurance companies.[1]

[1] Mill or heavy interior frame construction which is extensively used in factory buildings was developed, it is said, by the Associated Factory Mutual Insurance Companies of New England as a means of reducing fire hazards. Although of wood, it is classed as slow-burning on account of the large timbers used, and enjoys much lower insurance rates than does steel-frame construction, which, if not fireproofed by incasing the supporting steel members in concrete, is quickly destroyed by fire.

The development of reinforced concrete and steel-framed window construction has supplied a type of building which in some respects is superior to the older wooden interior framing. It is in most localities still of higher first cost but, because of its obvious structural advantages, is rapidly becoming the choice of manufacturers for multiple-story construction. Its advantages lie in low maintenance cost, resistance to fire, and increased possibilities of natural lighting. In the older type of mill construction, the brick walls function as floor supports and in consequence must not be weakened by excessive window areas. In the newer type, the floor weight is carried by the reinforced concrete frame, and the intervening wall spaces are frequently almost altogether given over to windows. Working conditions have thereby been improved, and the practical width of buildings has been increased.[1]

For one-story building construction, the steel-frame type is usually employed. It is common practice to plan the interior as a series (usually three or four) of parallel bays which extend longitudinally through the building and are separated from one another by rows of steel columns which provide support for steel roof trusses. Here also the width of the building is limited by the window areas, which, however, are often increased by roof lighting either of saw-tooth or monitor type. The former, when faced to the north, provides excellent lighting without glare and is much used for machine-shop construction. The monitor type is usually formed by raising the roof of the central bay above those on either side and placing windows in the monitor walls. This arrangement provides additional light for the interior bay which is farthest from the outside walls, and provides excellent ventilation. For the latter reason it is a type often used in foundries, rolling-mills, and like plants where fumes and gases must be disposed of. In both types, cranes and overhead equipment required for interior material movements are usually carried on auxiliary steel frames which are independent of the building supports.

[1] Building widths are limited by the height of the windows, if natural light is to be relied upon. It is commonly estimated that an area four times the height of the windows in width is the maximum space which can be lighted without artificial means. From this it is common practice to deduct from 20 to 25 per cent as an allowance for dirty windows and interior obstructions such as posts, belting, etc. Thus, in a building with windows eight feet high on both sides, the maximum allowable width, if artificial lighting is not to be necessary, is approximately fifty-two feet. The distance between buildings is also an important factor, of course, and should never be less than the height of the buildings if this rule is to be applied.

Economy of Maintenance.—Maintenance costs are in large measure dependent upon the character of the materials chosen for building construction. The desire to reduce these costs and forestall rapid depreciation often justifies the selection of so-called "permanent" construction when less costly structures could supply immediate needs as well. As in most engineering problems, the decision depends upon a comparison of costs. If sufficient data concerning the life-expectancy of the various possible types of construction are available, little difficulty is experienced in reaching wise conclusions.

The chief causes of deterioration for all material assets are (1) the action of the elements and (2) the wear and tear caused by operation.

The exterior of the building is naturally most susceptible to attacks of the first sort. Weathering may practically be eliminated by the choice of proper materials for foundations, walls, and roof. It has many times been found, however, especially in the case of roof coverings, that some of the less enduring materials are cheaper in the long run even though requiring frequent renewals. Roof repairs seldom entail interruption of manufacturing operations, and the ease with which repairs and renewals can be made to many modern composition roofing materials causes them generally to be preferred by factory-designers. Their low initial cost, their adaptability to all kinds of roof conditions, their resistance to fire, and their light weight necessitating slight expenditures for supporting framework enable them to compete on very favorable terms with older, and in many cases more permanent, types of roof construction.

The factory floor is the point most susceptible to wear and tear in operation. In some processes in which fumes and humid atmospheric conditions prevail, as in paper mills, the overhead construction, especially if of wood, is subject to rapid deterioration; but damage of this nature can be avoided by the choice of more enduring materials for ceiling construction. The floor, particularly when exposed to heavy trucking, is likely to be a source of constant expense. The cost of renewal may be deferred or decreased, however, by specifying wear-resisting materials such as paving brick or wood blocks, which are designed to withstand hard service.

Another aspect of building maintenance cost which is closely related to building design embraces such items as factory heating and air con-

ditioning. A building which is provided with large window areas affords excellent lighting but is subject to excessive radiation, and comparisons often prove the wisdom of restricting fenestration for this reason. Some added expense in supplying artificial lighting is thereby incurred, which is, however, often offset by the decreased cost of operating an insulated building. An extreme illustration of this nature is afforded by cold-storage warehouses, the walls of which, as constructed, are almost devoid of openings. The same problem is encountered, though in less degree, in designing any factory where uniformity of temperature and the comfort of bench workers and machine attendants employed at tasks involving little physical exertion must be considered. In making decisions concerning such matters, the designer must be guided by comparisons of expected cost. These usually can be predicted with considerable certainty.

Reduction of Hazards.—Closely related to economical maintenance is the problem of eliminating hazards and possibility of loss from various causes, including floods, explosions, and fire. Flood hazards may be avoided by proper location of the plant and seldom need to be considered by the designer. Serious explosion hazards are confined to the relatively few industries dealing with volatile materials.[1] Powdered coal, the dust of grain in elevators and flour mills, gasoline and nitro compounds of various kinds, are well-known examples of materials which, if not properly handled, are likely to explode and cause serious damage and loss of life. Proper ventilation, careful manipulation, and correctly designed equipment greatly reduce, but cannot entirely eliminate, the risks involved in processes of this sort which usually are segregated in order to localize the possibility of damage in case of accident.

Fire hazards, on the other hand, are common to all industries and can never be disregarded by the designer of the plant, for risks of this kind may be greatly reduced by approved design. The use of non-combustible materials of construction, the employment of wire glass for window construction, the placement of fire walls and fire doors, and proper arrangement of stairways, elevator shafts, fire escapes, or other means of exit, all of which are matters of design, have greatly reduced

[1] The Bureau of Chemistry of the United States Department of Agriculture has estimated that there are approximately 21,000 manufacturing plants in the United States which are subject to explosion risks. The dusts of grain, powdered milk, fertilizer, rubber, soap, spice, sulphur, cocoa, cork, paper, aluminum, and magnesium have been known to explode.

industrial fire risks.[1] Such precautions, if they do not prevent fires, at least retard their progress and minimize the risks of property damage and loss of life, thereby resulting in direct reductions in operating costs by securing low rates of insurance.

The introduction of the automatic sprinkler has also been a very important aid in preventing destructive fires. Fireproof building construction does not prevent the burning of inflammable materials or equipment, and it is in extinguishing and preventing the spread of fires of this kind that sprinkler equipment has proven invaluable. Automatic sprinklers were first introduced about 1880,[2] and their use has become almost universal. They require very little attention, are entirely automatic in operation, and have gained such an enviable reputation for effective fire prevention that no sensible manufacturer will omit them from the specifications for his factory building if fire hazards exist. Insurance companies have been quick to recognize their worth, and the saving in insurance will under ordinary circumstances pay for the cost of the installation long before the building investment is amortized.[3]

Layout and Accessibility.—A successful manufacturer, when discussing the layout of his plant in which he took just pride, once remarked to the writer that a manufacturing plant should be built around the scheme of interdepartmental material movements. He might well have broadened this statement to include off-plant as well as on-plant or inter-departmental material handling, for plant operations begin at the factory gate, where inbound materials are received, and end at the shipping dock. Processing departments need merely to be placed in proper relation to other departments from which they receive materials or to which these materials must be moved for further processing. Receiving and shipping departments, however, must be accessible both

[1] That industrial fire risks have continually declined in recent years is shown by the experience of insurance companies as given in the annual report for 1926 of the Boston Manufacturers Mutual Fire Insurance Company. Fifty years ago the rate of loss on the amount of insurance written was $0.2529 per $100. By proper design, in which sprinkler services have played a considerable part, this rate has been reduced to $0.0206 per $100.

[2] The first successful sprinkler system is credited to Henry S. Parmalee, of New Haven, Connecticut, in 1874.

[3] In 1926 in nearly 2,000 industrial fires in sprinklered buildings, extensive damage was prevented in 96.5 per cent of the cases reported. This remarkable record is reflected in fire insurance rates, which were reduced an average of 76 per cent in 860 industries of wide variety by the installation of sprinklers, according to evidence supplied by the statistical department of the Grinnell Company.

to off-plant transportation connections and the processing departments which compose the plant. In small factories where off-plant movements are sometimes made almost entirely by truck, proximity to loading and unloading docks near the street entrance is all that is required; but in large plants depending upon railway transportation, other factors are introduced. Freight cars can be moved only where tracks have been laid, a fact which often makes it advisable for the designer to defer the arrangement of the factory buildings until the industrial trackage has been planned. In locating these rail lines, two important considerations are involved:

1. The limitations imposed upon switching operations by track alignments.
2. The desirability of providing entrance to each department to which access is required without interfering with material movement to and from other departments.

It is desirable to avoid, as much as possible, the use of curves in industrial-track alignments. Curved tracks require much space unless a very short radius is employed. Sharp curves, on the other hand, are objectionable on account of the fact that they increase the risk of derailments[1] or may even make it impossible to switch cars in the usual way altogether. As an extreme illustration of the latter sort, Tratman[2] cites an instance where, in order to serve a warehouse located in very cramped quarters, it was found necessary to spot cars one by one by means of a cable because switch engines could not be operated over the sharp curves of the lead track. Such methods obviously cannot be tolerated where many cars must be moved at frequent intervals.

The second consideration refers to the inadvisability of attempting to serve more than one department by the same track. With such an arrangement cars which have been "spotted" for one department must necessarily be moved in order to gain access to another, thereby causing interference with material movements. The difficulty may be avoided by either constructing separate tracks for each department or by providing access to the single track at both ends.

[1] "Freight cars cannot be handled even singly on tracks of less than forty or fifty foot radius. Where two or more cars are to be handled with ordinary M. C. B. couplers, curves of at least 140-foot radius are necessary which is also the approximate minimum limit for six wheel switch engines. Where fast switching of heavy loads is desirable curves should not be less than 400-foot radius" (J. A. Droege, *Freight Terminals and Trains*, pp. 42–43).

[2] E. E. R. Tratman, *Railway Track and Track Work*, p. 401.

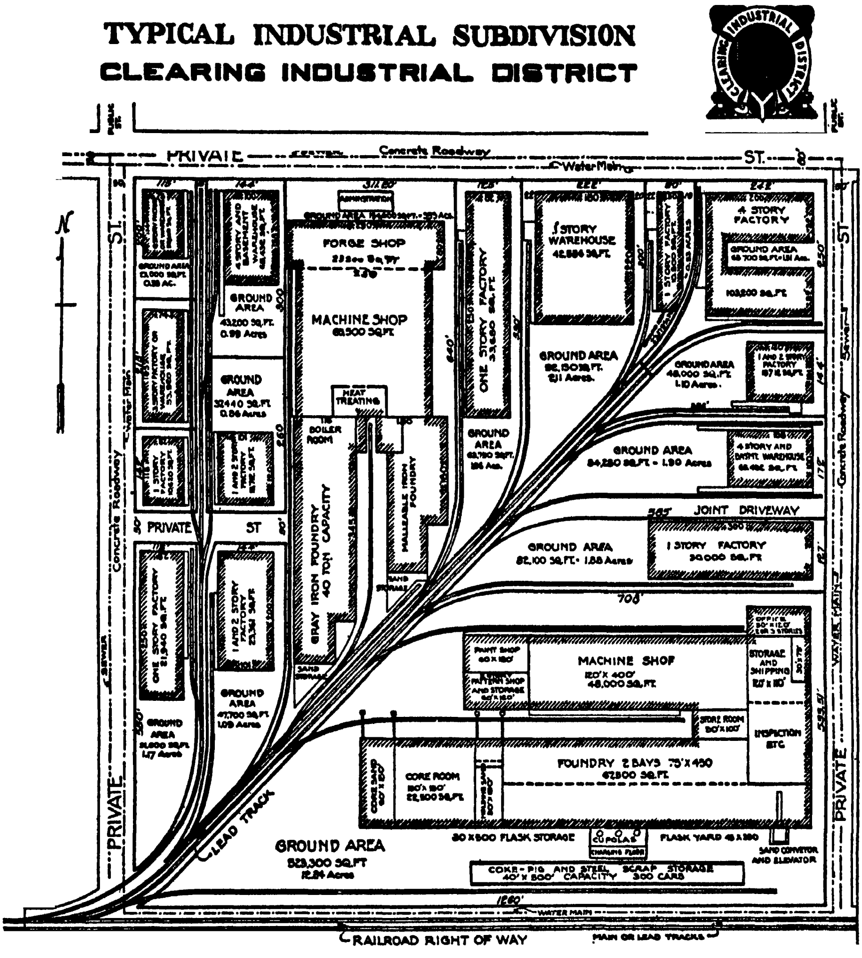
A system of tracks which serves a number of industries in a new industrial district and meets both these general requirements in admirable fashion is shown in Figure 1. The diagonal "lead" track designed to serve this site economizes space and makes it possible to reach every part of the subdivision with an economical and efficient switching track. Figure 2 is an illustration of a single large industrial layout in which the system of on-plant trackage provides a high degree of accessibility. An important feature of this layout is the location of the plant buildings at an angle to the service tracks on either side, thereby reducing curvature in the leads and facilitating switching at high speeds.

Direct-Line Production.—Figure 3 serves to illustrate another important characteristic of a well-designed plant. Processing departments, it will be noted, are arranged in such a manner that materials can be moved always in the same direction. This plan, commonly known as "direct-line production," which has long been used in continuous processes, such as flour-milling and sugar-refining, has now been adopted almost universally in assembly departments and machine-shops where related operations must be performed in a given sequence. By the exercise of forethought when the plant is being designed, direct-line production, with its obvious advantages and economies, may even be secured in jobbing or special-order plants where intermittent processing is necessary.

The Arrangement of Machines.—The principle of direct-line production is one which may be applied to the arrangement of production centers as well as processing departments. Every manufacturing process necessitates bringing together at the appointed time the three factors: workers, machines, and materials. Obviously there are three possible ways in which this may be done:

1. The worker may be stationed at a given point in the shop to which tools and materials are brought as required.
2. The worker and the machines may be brought to the material.
3. The worker and materials may be brought to the machine, in which case its location in the shop determines where the work shall be done.

Since the workman is more mobile than either of the other factors, naturally the first method is rarely used. The second method, however, is frequently employed in heavy engineering work. In car shops, locomotive plants, and shipyards, for example, the product is so unwieldy



Courtesy of Clearing Industrial District, Chicago, Illinois

FIG. 1.—Diagram showing efficient layout of tracks designed to serve a new industrial development. This plan of street and track layout provides for the following important and desirable conditions: (1) sites of small or large area which provide as nearly as possible the exact requirements of each industry as to size and dimension of land; (2) diagonal "lead" track saves land, and gives a cheaper and more efficient private switch track, which can be placed at any part of site; (3) all sites have street frontage and ready access to sewer, water, and gas mains, electric lines, etc.; (4) street frontage and cost of paving, etc., reduced to a minimum; and (5) railroad track arrangement provides most convenient and rapid switching operations; no tracks in streets.

that it would be impracticable to move it from place to place during the process of manufacture. The materials required for each unit are accordingly delivered at some designated point in the shop, and the machines and workmen are brought to the job.[1]

The third method in which the machine is stationary and materials are moved from machine to machine as the work progresses is, of course,

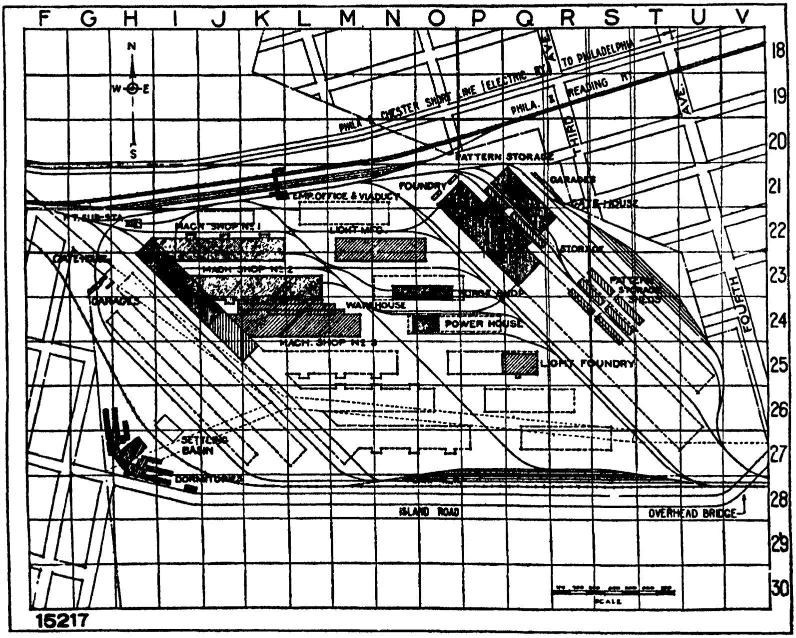


FIG. 2.—Diagram showing an arrangement of factory buildings which conforms with an efficient track layout. Reprinted with permission from *Management and Administration*, IX (January, 1925), 12.

most frequently employed. An interesting example of this method, commonly known as "chain assembly," is illustrated in Figure 4, which shows the interior arrangement of a cement plant. In this layout also, materials flow continuously in a forward direction. It is easy to secure direct-line production in a plant of this character since only one prod-

[1] An interesting example of this method, known as "spot assembly," is found in the shops of the General Electric Company's Schenectady Works, where the manufacture of huge generator parts is carried on. Even large boring-mills and other metal-cutting machinery not ordinarily regarded as portable tools are moved to the work rather than the work being moved to them, as is ordinarily the case. This method is described in detail in *Manufacturing Industries* for April, 1927, pp. 291–92.

uct is manufactured and at no two stages of the process are identical machines used. In industries where similar machines are employed at different stages of the process, it is usually necessary to place these similar machines in different parts of the shop if direct-line production is to be realized.

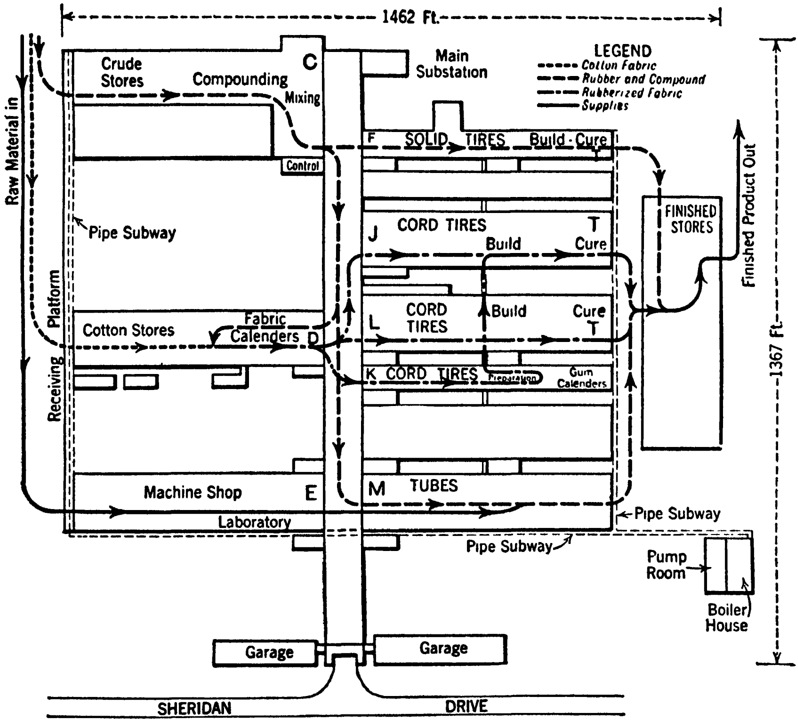
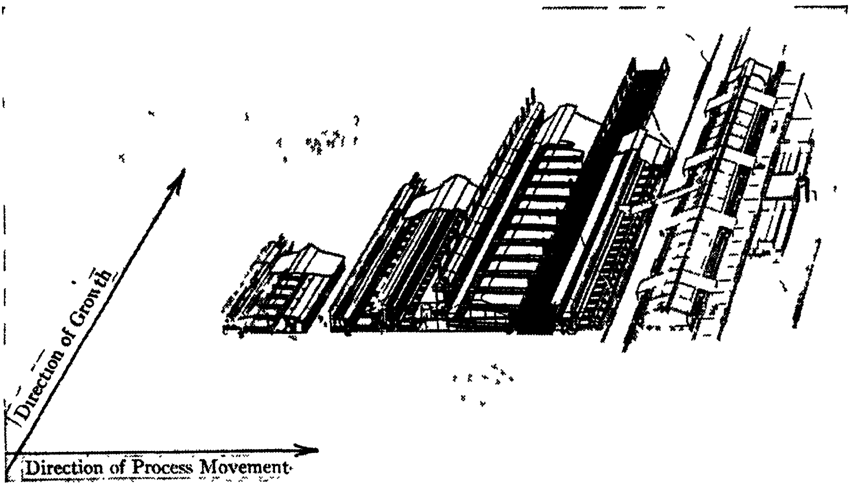


FIG. 3.—Diagram showing a plant layout in which direct-line production has been realized. Reprinted by permission from *Manufacturing Industries*, XIV (December, 1927), p. 426.

The alternative, of course, is to group machines according to similarity rather than according to processes, and it must be admitted that there are often distinct advantages in having all machines of a given kind grouped together in the shop. Identical machines have identical power requirements and, if located together, may take their power from the same line shaft. This is not always feasible where unlike machines are grouped together. Similar machines require the same kind of supervision and attendance; and in case of breakdown, work may

readily be shifted from one machine to another without seriously disrupting the usual routing of operations in the shop.

Such advantages are in many instances sufficient justification for this method of arrangement. If the machine performs a semi-independent operation, as in the case of looms in a textile mill, monotype or linotype machines in a printing plant, or automatic screw- and gear-cutting tools in a machine shop, this arrangement is almost always employed. It is only when direct routing is important that much is to be gained by grouping machines according to processes.



Courtesy of, and copyrighted by, the Universal Portland Cement Company

FIG. 4.—Diagram showing the process layout in a modern cement plant

Layout and Power Transmission.—Improvement within recent years in the method of power transmission has given the plant-designer much greater latitude in the placement of machines than he formerly possessed. As long as the only means of bringing power from the power plant to the tool in the shop was by belt or line shaft, obvious limitations were placed upon the location of machines. Indeed, a large plant under such circumstances was impracticable unless the power plant itself was decentralized and prime movers were placed in each department.[1]

[1] An example of this method of power distribution which was very common until a few years ago was the rolling-mills of steel plants. It was the usual method for each rolling-mill to be provided with its own means of power, usually a steam engine. This rather cumbersome arrangement has been supplanted in all modern mills by independent reversible motors which are directly connected to the line shaft of the rolls.

In all modern plants, power in the form of electrical current is transmitted to all parts of the shop where it is utilized by individual or gang motors, and the location of the machine is no longer limited by the location of the power plant.

Provision for Future Development.—A common error in plant design is neglect to provide for future expansion. In an inquiry made several years ago, 89 of the 132 plant managements which were interviewed cited this as the chief mistake which has been made in designing their plants.[1] Perhaps the most important consideration in making such provision is to plan the layout so that subsequent additions may be made without interfering with the facilities already in existence. Dean Kimball has suggested what is doubtless the most practical way of meeting this requirement when he states that, in general, the direction of expansion should be at right angles to the direction of flow of production in the plant.[2] The application of this method is clearly shown in Figure 4 already mentioned. Wherever this general scheme can be adopted, existing facilities need not be molested while additional plant space is under construction.

The Conservation of Energy.—In concluding the discussion on this subject, the point of view which has been repeatedly implied in this chapter should be emphasized. A manufacturing plant should be regarded merely as a complex machine which is designed to perform a certain series of production operations. Its efficiency is to be measured in the same manner as that of any other mechanical device. The ratio between the energy expended and the useful work done is the measure of performance employed by machine-designers and is of significance to the plant-designer as well. The latter can perhaps exert little influence upon this ratio in so far as it is determined by the work done at the machines. That is the responsibility of the designer of the individual machine. But he can exert a profound influence upon this ratio in so far as it pertains to material movements in the plant. The energy required for performing this phase of the manufacturing process is directly determined by the plant layout.

[1] H. T. Noyes, *op. cit.*, p. 89.

[2] D. S. Kimball, *Principles of Industrial Organization* (1925 ed.), p. 79.

CHAPTER V

PLANT TRANSPORTATION

Importance of Material-Handling.—The primary function of the production department is to transform raw materials into finished goods. Its performance is rightly judged by its output, and every operation in the plant is of value only in so far as it forwards that end. Many necessary plant operations, however, are not directly associated with the transformation of commodities into finished goods. Materials must first be procured, unloaded, stored, and moved to the machines or departments where the manufacturing operations are performed. As the work proceeds, goods in process must be moved through the plant. Upon completion finished goods must be moved to the stockroom or shipping dock. At every stage materials must be moved, but the importance of these material-handling operations in comparison with actual processing operations often has not been fully appreciated by production managers. Until recently direct costs received relatively more attention by plant executives and cost accountants than did indirect costs, which may explain why in many plants improvement in processing methods has progressed more rapidly than improvement in the methods of material-handling. As one writer observed a number of years ago:

> It is a paradox that, while everybody has long recognized the importance of efficient transportation of goods from producer to consumer, little thought has been given until recently to improving methods of transporting goods in process of manufacture. Industry demands steam, electricity, and the internal combustion engine in the one case, but has generally been content with man power in the other. The incongruous spectacle may still often be witnessed of marvelously ingenious automatic machinery for *making* things used side by side with crude non-automatic methods of *moving* them.[1]

Since the World War, however, the relative scarcity of unskilled labor, which in general constitutes the indirect labor supply of industry, has served to focus the attention of management upon this division of manufacturing costs and has accordingly provided the needed incentive for a complete revolution in material-handling methods.

The thorough mechanization of plant transportation which has been

[1] C. F. Talmon, *Outlook*, November 11, 1924, p. 385.

witnessed during this post-war period has been attended by very important results, since in many plants the cost of handling materials comprises a considerable proportion of manufacturing costs. It has been estimated, for example, that in the ceramic industries from 70 to 90 per cent of the cost of manufacture is attributable to material-handling,[1] and some years ago it was found that in one presumably well-managed foundry 168 tons of materials of various kinds were being moved from one part of the plant to another for each ton of finished castings delivered to the machine shop. Assuming that similar conditions existed in the machining and assembly departments through which this product necessarily passed before being ready for sale, it was estimated that the cost of one ton of the finished commodity included the expense of handling 224 tons of material in the plant.[2]

It is true that material-handling conditions in foundries and brick plants are extreme and supply no measure of the importance of this item of expense in other manufacturing enterprises. The problem of plant transportation in a shoe factory or a textile mill differs considerably from that ordinarily encountered in a machine-tool shop, a flour mill, or a steel plant. The methods for handling materials are as different as the processing methods, depending upon the nature of the commodities and manufacturing processes, the layout of the plant, and the character of the equipment and labor which are employed. It is certain, nevertheless, that in practically every industry material-handling comprises a significant element of manufacturing cost.[3]

Happily, the importance of material-handling costs have gradually been recognized by manufacturers, and—what is more to the point—these costs have been found to be just as amenable to control as any other costs of production. Many of the most significant cost reductions in recent years have been effected in this connection. Mechanical equipment has been substituted for common labor which has heretofore argely been employed in industry with shovel and wheelbarrow in

[1] *Brick and Clay Record*, June 22, 1926, p. 1015.

[2] M. Slovsky, chief engineer of Deere and Company, as quoted in the *Annual Report of the Materials Handling Division of the American Society of Mechanical Engineers, December, 1925*, p. 1117.

[3] In an inquiry by *Factory* in 1925 in which some 30 widely different industries submitted data with respect to their material-handling costs, this item of expense was found to be equivalent to from 5 to 80 per cent of the factory pay-roll, depending upon the type of plant and processes involved. (*Factory*, August, 1925.)

moving bulk materials from one place to another.[1] No doubt, as already suggested, these improvements in production methods have been hastened by the fact that the wages of unskilled workers have within recent years materially increased in comparison with those of skilled workers who ordinarily are employed in the processing departments. But a still more potent reason in many modern industries has been the discovery that it is physically impossible for a human being to move materials by hand fast enough to keep pace with mass-production requirements.

Material-handling Economies.—Systematic study of the plant transportation problem has often led to astonishing results. In one large enterprise, for example, where 550 men were required for handling materials several years ago, the number was reduced to 55 through the adoption of improved transportation methods and equipment. Another large manufacturing company reports that it has been able to save $300,000 annually in handling costs as the result of improvements in its inter-departmental transportation system. And in an investigation which included the experience of fifteen plants where careful consideration had been given to plant transportation, the average saving in handling costs reported was 52.2 per cent. This represented an average annual return of 270 per cent on the required investment in handling equipment.[2]

These economies are typically attributed to a variety of causes:

1. The reduction in the indirect labor pay-roll and the increased productivity of workers resulting from the substitution of power-driven mechanical devices for hand labor.
2. The saving in time and the elimination of delays resulting in increased productivity of processing equipment.
3. The conservation of factory floor space as a result of more effective plant layout made possible by improved material-handling methods.
4. The reduction of process-inventory investments resulting from the speeding-up of material movements.
5. The elimination of material breakage and spoilage through the use of properly designed conveying equipment.

These possibilities are nowhere more strikingly illustrated than in

[1] M. W. Potts, *Industrial Transportation Facilities Manual 29* (LaSalle Extension University).

[2] As reported in a *Manual of Industrial Transportation* published by the Lakewood Engineering Company.

the well-known "conveyorized" assembly departments of modern automobile plants. The same methods are applicable, however, in many other departments where the work is of sufficient volume to justify the installation of modern equipment.[1]

Relation of Material Transport to Plant Layout.—The demands made upon internal transportation equipment are in large measure dependent upon the design or layout of the plant. In many instances, and especially where intermittent processes are carried on in semi-independent departments, it is internal transportation which provides the physical tie that binds these operating units together in one co-ordinated whole. In other plants, the movement of materials is so closely identified with the actual fabricating processes that it is difficult to draw any clear line of separation between the two operations. In the latter type of industry, transportation has in reality integrated the various processing units to such an extent that the entire plant may be regarded as a single machine. In the manufacture of cement, for example, the materials move forward in a continuous stream from dryers to grinding-mills and thence to kilns and still other grinding-mills. The entire plant functions as a single machine. The conveyors which perform the service of moving the materials from one stage to another are as much a part of that machine as the kilns and crushers which effect the actual transformation.[2]

From the point of view of plant layout, however, there is one important distinction to be made between material-handling and material processing equipment. Unlike the processing units, conveyors render a service of place utility, and the cost of this service depends upon the

[1] An interesting example of continuous production made possible by the use of conveyors is afforded by certain large foundries. Instead of placing the molding-flasks upon the foundry floor in the traditional way, where they are poured and allowed to stand until cool, they are placed on a "merry-go-round" conveyor around which the various charging facilities and workers are stationed in such a manner that each operation can be performed as the conveyor moves forward, the flask being prepared, poured, and the completed casting being broken out by the time the circuit has been completed. In one plant this method has, according to reports, increased the productivity of the foundry an average of from 30 to 50 per cent, has made it possible to reduce the floor space to one-fourth of the area formerly required for the same output, and has resulted in a saving of $50,000 in the investment in flasks required. (R. Fiske, *Iron Age*, March 11, 1926, pp. 677–79.)

[2] In extreme instances of this sort, the conveyor has been incorporated within the processing unit itself, as in cement burning-kilns, dryers, and annealing ovens. For a suggestive article in this connection see, "What Transportation Is Doing for Industry," by C. Piez, in *Industrial Management*, August, 1926, pp. 64–68.

distance the materials must be moved. The processing elements often could be made to function as well in one position in the plant as in another, but the cost of moving materials between these elements depends entirely upon their position with respect to one another. The plant-designer is therefore chiefly concerned with securing a layout for the plant which will minimize transportation charges.

Types of Transport Service.—In giving consideration to the transportation problem, it will for some purposes be useful to distinguish between three types of service, each of which must in some degree be provided in every industrial plant:

1. *Material loading and unloading services:* Inbound and outbound materials must be received or prepared for shipment as the case may be, which involves handling operations in the storage yard, the storehouse, and the shipping-room. Relatively short movements—lifting, tiering, and lowering—are characteristic of this type of service. Frequently, a high degree of adaptability is demanded of the equipment employed in these departments. Its sphere of activity is, however, likely to be confined to a single department. The cranes, derricks, and cableways employed in storage yards and the portable conveyors often seen on car unloading docks are examples of equipment especially adapted for loading and unloading service.

2. *Interdepartmental movements:* Materials must be moved between departments, and such operations obviously must always affect interdepartmental relations. The distance materials must be moved may be long or short, depending upon the design of the plant and the nature of the processing departments. Nearly always, however, the equipment thus employed must possess flexibility of movement. Industrial railways, trucks and trailers, and even endless conveyors, are often used for this purpose.

3. *Intra-departmental movements:* Material-handling within the processing departments is often of special character; and the sphere of operations of the equipment which is assigned to such service may, if deemed desirable, be confined within the limits of a single processing department. Overhead cranes such as are employed in foundries and steel mills, and chain conveyors such as are used in packing plants, sawmills, and automobile assembly departments, afford examples of this type of service.

As indicated in the examples cited in each of these instances, the devices used may be designed for either "periodic" or "continuous"

service. The choice to be made depends largely upon the nature of the work. Conveyors or continuous-flow delivery devices lack flexibility and often represent relatively large investments in comparison with devices designed for making periodic deliveries. They thus are likely to prove economical only when constant service is demanded.

Classification of Transportation Equipment.—The selection of transportation equipment for service in specific situations involves many technical considerations, and it is not proposed in this chapter to carry the inquiry beyond mere mention of outstanding characteristics of important types of equipment in common use. Even to attempt to set forth a comprehensive list of the different kinds of devices found in industrial plants would serve no useful purpose. An examination of the catalogues of manufacturers of such machines soon shows that even those designed for rather general use are of great variety, and those designed to perform some special service are almost innumerable. A sufficient idea of the various kinds of equipment commonly employed is afforded by the following classification:

- A. 'Periodic" or lot-delivery equipment
  - Trackless carriers
    - Trucks
      - Manual
        - Caster skids and racks
        - Platform
        - Lift
      - Power
        - Platform
        - Tiering
        - Lift
          - Storage battery
          - Gas
    - Tractors
    - Combination
    - Trailers
  - Rail carriers
    - Standard gauge
    - Narrow gauge
      - Steam
      - Gas
      - Electric
        - Storage battery
        - Trolley
  - Overhead carriers
    - Cableways
    - Monorail
    - Cranes
      - Overhead traveling
        - Gantry
        - Girder
      - Cantilever
      - Boom (locomotive)
      - Pillar
  - Lifts
    - Platform elevators
    - Derricks
      - Guy
      - Stiff leg
    - Hoists
      - Chain and cable
      - Pneumatic
      - Steam
      - Electric
- B. 'Continuous" flow delivery (conveyors)
  - Gravity conveyors
    - Roller
      - Straight
      - Spiral
    - Pipe lines
    - Chutes
  - Pressure tube conveyors
    - Steam jet
    - Pressure pipe lines
    - Pneumatic tubes
  - Mechanical conveyors
    - Endless chain
      - Apron
      - Belt
      - Bucket
      - Hook
      - Flight
    - Power-driven rollers
    - Screw conveyors
    - Reciprocating (grasshopper)

Manual Trucking.—The hand-operated truck is probably the oldest type of material-handling device employed by industry. Until comparatively recent years it was practically the only means of transportation in many plants. In most instances it was first superseded by power-driven means in the handling of bulk materials such as coal, sand, cement, and grain, and exceptionally heavy objects such as steel beams, building stone, and lumber. The wheelbarrow and pushcart, however, are still often used in industrial storage yards where these materials must be moved. But with mounting costs of common labor, with the development of efficient and fast-moving trucks and tractors driven by internal combustion engine or electric motor, and with the gradual lengthening of the haul and the demand for a continuous transportation service as plants increased in size, the sphere of usefulness of hand-operated devices for moving materials has been so much restricted that they are fast disappearing in many modern plants. This substitution is explained by the obvious superiority of the power-driven device from both the mechanical and economical standpoints as demonstrated by comparisons of operating cost.[1]

There are some instances, it is true, where manual trucking can be economically employed. For occasional short hauls, as in a crowded corner of the storeroom or for moving loads to and from platform elevators which are inaccessible to power-driven trucks, this often proves to be the simplest and most economical means of transportation. Often, also, the hand truck may be used with profit for moving goods in process from one machine to another, particularly when the machine-operators themselves perform this service. In many plants, such as machine-shops and shoe factories, this method is thought to be desirable as a means of introducing variation in the routine of a monotonous machine-tending job. With these exceptions, there appear to be few instances in the modern plant where power-driven handling devices might not better be used.

Power Trucking.—Power-driven trucks of so many different kinds

[1] Where relatively long hauls are the rule and the service is required continuously, the economy of the newer device is readily demonstrated. It is usually estimated by material-handling engineers that a one-man truck can be operated under a load of 500 pounds at the rate of 1½ miles per hour. Power-driven trucks, on the other hand, can be operated under a 2-ton load at the rate of 4 miles per hour. With an estimated total operating expense of \$0.75 and \$3.00 per hour, respectively, the cost per ton-mile of the service for the former is \$2.00, as compared with approximately \$0.30 for the latter.

have been designed that, with the few exceptions indicated in the last paragraph, units may readily be secured which can be operated under any conditions where hand trucks may be used. Their chief advantage, as compared with hand-operated trucks, is their capacity for carrying heavier loads at greater rates of speed. This gives them a wider range of service at decreased cost per unit of work accomplished.

Three general types are in use: load-bearing trucks, tractors for drawing loads on trailers, and combination tractor-trucks designed both for carrying loads and drawing trailers. Both trucks and tractors are built with either three or four wheels. Four-wheel types are designed for steering by either two or four wheels and are also either two- or four-wheel drive. Speedy response to the steering device is, of course, a very desirable feature where trucks must be driven through narrow factory aisles and around sharp curves. In this respect the three-wheel type is the more flexible, though four-wheel steer trucks also are designed for turning in short radius. The four-wheel drive possesses the advantage of greater tractive effort, being in this respect almost twice as effective as a two-wheel drive truck of equal weight. This is an important characteristic where runways are in poor condition or grades are excessive.[1]

With respect to motive power, both internal-combustion engines and electric motors driven by storage batteries are in common use. In general the former appear to be preferable for heavy outside service, while electric trucks are more frequently used for light inside duty on account of their greater flexibility, quick starting and stopping characteristics,

[1] One of the advantages of trucks and tractors, as compared with industrial railways, is the fact that they require no trackage and thus are much more flexible and adaptable in operation. This feature can be much overemphasized, however, as many manufacturers have found when trucks designed to carry heavy loads have been installed without adequate provision for runways. The performance of the vehicle depends in large measure upon the nature of the roadway over which it must be driven, as illustrated by the following table giving the tractive resistances of various surfaces:

Brick	30– 50 pounds resistance per ton
Concrete	28– 40 pounds resistance per ton
Granite blocks	50– 60 pounds resistance per ton
Wood blocks	30– 50 pounds resistance per ton
Gravel	75– 85 pounds resistance per ton
Clay	200–400 pounds resistance per ton

(Adapted from the results of tests as published in *Railway Mechanical Engineering*, July, 1926, p. 454.)

and the absence of fire hazard, noise, and poisonous fumes from the exhaust.[1]

One of the most important recent technical developments in trucking devices from the standpoint of economical operation is the "lift" type, which in many instances is supplanting the older platform truck. The latter is provided with a non-detachable platform or hopper upon which the materials to be hauled are loaded and in turn unloaded when the destination is reached. The "lift" truck, on the other hand, is used for transporting skids or "tote boxes" upon which the materials have previously been loaded and which are in turn quickly laid down wherever the contents are required. With this method the productivity of the truck is increased, since it need not be delayed by the loading and unloading operations.

Still another innovation is the "tiering" type of truck, which in some instances is capable of raising its load a distance of seven or eight feet. This characteristic greatly facilitates the piling or tiering of materials in the storeroom, or the placing of heavy materials, such as rolls of paper, dies, and castings, in position in machines for further processing. Supplementary hoists in the shop may thus often be dispensed with since the lifting service is provided by the truck which delivers the material to the work place.

Industrial Railways.—Industrial railways, which are merely an adaptation of ordinary railway transportation to on-plant conditions, came into general use much earlier than did the power-driven truck or tractor, since the internal combustion engine and electric motor upon which the latter type of equipment depends are comparatively recent developments. For some kinds of service, trucks and tractors have obvious advantages and are accordingly supplanting the rail carrier, but there are still many situations in which the railway has demonstrated its superi-

[1] There appears to be some difference of opinion among plant executives as to the relative merits of these two general types of motive power. In many plants electrically driven trucks are used altogether, while in at least one large plant with which the author is familiar gas-driven trucks are in some departments being substituted for electric trucks as fast as the latter which were originally installed are worn out. The reason for this change is reported to be the impossibility of securing a truck operated by a storage battery which can be used on heavy duty for a full day without delays for recharging. An attempt is made to design storage batteries of sufficient capacity to enable all recharging to be done at night when the truck is off duty, though in some plants a "booster" charge is provided for during the noon hour. On the other hand, it is considered uneconomical to provide storage capacity much in excess of a single day's requirements on account of the excessive investment and "dead" weight which is thereby entailed.

ority. Its particular sphere of usefulness is in inter-departmental transfers in large plants in heavy manufacturing industries such as sawmills steel plants, and the like, where relatively long hauls and little flexibility are required.

In capacity, industrial railways range from ordinary standard-gauge equipment to diminutive units operating on narrow gauge and very light weight rail. Gauges of 24, 30, and 36 inches are commonly employed, though practical installations vary in width from 18 to 56½ inches, the latter being the gauge of the standard railway. Rail of varying weight is employed depending upon the nature of the service, ranging from 12 or 18 pounds up to 75 or 90 pounds, such as is commonly used for fairly heavy traffic by standard-gauge railways.[1]

Motive power of great variety, including steam, gas, storage battery, or electric trolley, is used. Standard-gauge and heavy-duty-narrow-gauge locomotives are usually steam driven, and closely resemble those employed by common carriers for switching service. Electrically driven locomotives have some mechanical advantages over those driven by steam and gas, since the turning torque of the electric motor is uniform and does not tend to "slip the wheels" in starting. This is an important advantage in industrial service where frequent starting and stopping under heavy load is necessary. But on the other hand, electric locomotives have some serious shortcomings in so far as industrial service is concerned. Storage-battery locomotives are suitable only for short-haul work, often not exceeding 2,000 feet for the round trip, while third-rail and trolley transmission is defective in point of safety and overhead obstruction within the plant.

For heavy duty the industrial railway compares very favorably both as to economy of original investment and subsequent maintenance with the trackless carrier. Tracks must be provided, but these seldom cost more than the runways which trucks and tractors under heavy load require if satisfactory results are to be obtained. Suitably designed locomotives cost little more than tractors of equal capacity and require less for upkeep and repair. At the same time, cars cost less than trailers of equal capacity and similar design, since no steering mechanism is required, as is the case with trailers if perfect trailing on sharp curves is desired.

[1] Steel rail sizes are designated by weight; thus a 75-pound rail is one of standard dimensions weighing 75 pounds per yard.

From the standpoint of efficient plant design and operation, rail transportation raises certain special problems. Little discernment is required to appreciate the fact that the problem of designing a satisfactory on-plant trackage system is completely interwoven with that of the arrangement or layout of the departments which must be served. Equipment of this general type is subject to rigid operating restrictions. When once the tracks are laid, there is little opportunity to effect needed changes. For this reason much more satisfactory results are likely to be secured if the entire problem of plant transportation is thoroughly analyzed when the plant is being designed. It would be useless to attempt to formulate general working rules concerning such matters, since conditions vary so much from plant to plant. There are, however, at least three considerations which are of such universal application that they deserve special mention:

1. *Importance of avoiding interference between inbound and outbound shipments:* Most large plants ordinarily receive materials and ship out finished goods by rail. In both of these movements it is desirable, wherever possible, to transport the goods to or from the point of storage adjacent to the processing departments in the vehicle used by the delivering or receiving carrier. This plan avoids rehandling of materials, but may, of course, make it necessary to introduce standard-gauge tracks within the plant itself.

In plants which require no other standard-gauge railway service, it is customary to arrange for the delivering or receiving carrier to place and pick up cars at the desired points on the plant, in which case the carrier assumes full responsibility for all on-plant switching and bills the plant at standard rates for the service. Where the plant owns and operates its own standard-gauge motive power, on the other hand, arrangements are frequently made whereby the carrier merely picks up or places cars in the outbound and receiving yards of the plant, the movements to or from on-plant points being performed by the plant's own transportation department.[1]

[1] Sometimes, as in the Chicago plant of the Illinois Steel Company, for example, inbound, outbound, and on-plant inter-departmental standard-gauge traffic movements are all performed by an outside carrier. The standard-gauge track system in this plant is over a hundred miles in length, and the volume of traffic handled would compare favorably with that of many railway terminals.

2. *Minimizing of switching on the plant:* This is primarily a problem of plant design the importance of which was sufficiently emphasized in the last chapter.[1]

3. *Elimination of "bottle-necks" in the track layout:* These most frequently occur in lead tracks to and from the plant or in connecting lines between different parts of the plant. At such points congestion is almost sure to cause delays and increased switching costs. If the transportation problem is carefully analyzed when the plant is being built, crowded conditions can usually be foreseen and avoided by providing for the separation of opposing streams of traffic and the construction of "run-around" tracks; but once the plant is built, such remedies are likely to be very difficult to apply.

Another serious source of congestion frequently arises out of the difficulties of co-ordinating rail and other means of transportation. Intersections of standard gauge, narrow gauge, and truck lines of traffic seldom can be entirely avoided in the large plant, and some friction is almost certain to occur. When the ingenuity of the plant-designer is not equal to the task of avoiding such interference, the only remedy lies in unified control of operations with a view to minimizing delays.

Overhead Carriers.—Overhead carriers which include cableway and monorail devices and cranes of many different kinds possess an ever widening range of usefulness in industrial plants. They usually are electrically driven and probably could not have reached their present high stage of technical development were it not for the electric motor.[2] Their chief advantages are derived, first, from the fact that most of the operating mechanism is elevated, thus causing a minimum of interference with operations on the factory floor, and second, from their capacity for functioning in both the horizontal and vertical planes. For these reasons they are much used in steel mills, foundries, and machine-shops as well as in storage yards where bulky materials must be moved and piled.

Overhead carriers, obviously, are unsuited for long-haul transportation, although gantry and cantilever cranes which ordinarily are oper-

[1] See pages 59–60.

[2] Overhead carriers are, of course, not limited to "periodic" or lot-delivery devices such as mentioned above. Continuous conveyors of the gravity, pressure tube, and endless-chain type are also "overhead" carriers. This is not, however, an essential characteristic of these devices; and when they are so designed, no distinctive operating features are introduced.

ated on ground laid tracks, and boom cranes which may be mounted on rail or caterpillar trucks, may be designed to serve efficiently all parts of an extensive material yard. Heavy-duty monorail carriers and the overhead girder type of traveling crane, however, are seldom employed beyond the confines of a single department because of the costly supporting structure which they require and their unsuitability for high-speed transfer service.

Elevator Service.—The term "elevator service" is used to designate all devices which function primarily in moving materials in the vertical rather than the horizontal plane.[1] It will at once be apparent that this includes appliances of almost infinite variety, ranging from the portable hand-operated hoist with few mechanical refinements not possessed by the ancient block and tackle to high-speed freight and passenger elevators which are essential adjuncts of modern multiple-story plants. It would be useless to attempt to formulate any general principles which would apply to so many different kinds of service. Merely to suggest the importance of submitting this aspect of the transportation problem to the same careful analysis accorded its other numerous phases is sufficient for our present purpose.

Continuous-Conveyor Equipment.—In popular fancy, the continuous conveyor is by far the most interesting and spectacular transportation device employed in industry. Its successful and much advertised application in a wide variety of industries, and particularly in the manufacture and assembly of automobile parts, has largely been responsible for this notoriety which doubtless has served industry well in focusing attention upon the importance of the entire problem of plant transportation. Though until recently a type of equipment but little used save in a few isolated industries, the continuous conveyor is by no means a new invention. One of the first practical applications of this device to industrial transport in American industry is credited to Oliver Evans, who over a century ago constructed a flour mill in which he installed bucket conveyors in no essential differing from those employed by all modern mills.[2]

[1] Here, as in the preceding group, it should be noted that the continuous conveyor has a wide range of usefulness. In grain elevators and flour mills, to cite but one example, where material movements are largely confined to the vertical plane, the continuous conveyor is almost universally used.

[2] This device, as well as other interesting inventions, was described in *The Young Mill-wright and Miller's Guide* by Oliver Evans, published about 1790.

Concerning the origin of contrivances of this general type, with the exception of the screw conveyor, which is generally supposed to have been invented by Archimedes and used in ancient Greece for raising water from the holds of ships, little is known. Certain it is, however, that the endless chain, such as Evans used, was commonly employed many centuries before the Christian era. To such chains were fastened buckets or flights which engaged the material to be transported at the receiving end of the conveyor and carried or pushed it along a trough through which the chain or belt operated, depositing it in a more or less constant stream at the discharging end. This device, which was admirably suited for the handling of bulk materials, was clearly the forerunner of the modern industrial conveyor. The sphere of usefulness of conveyors has been much expanded, however, until today many types employing a number of mechanical principles are in common use for transporting all kinds of commodities. A list of those most frequently encountered in industrial plants has already been given on page 71.

Conveyors employing the principle of gravity are much used for loading and unloading service, for carrying materials from one level to lower levels in processing departments, and within obvious limits for movements on a single floor—in fact, wherever the slope of the conveyor can be made sufficient to overcome the frictional resistance generated on the sliding surface. Pipe lines, rollers, and incline planes are commonly employed, the choice depending upon the character of the materials to be transferred. Where space is limited, the latter two types often are constructed in the form of a spiral, thus avoiding excessive grades and permitting safe transportation of fragile commodities.

Pressure tubes have, of course, long been used for handling liquids, but by the use of air pressure this type of conveyor has been given a wider range of usefulness than is generally recognized.[1] Almost any bulk material which is self-feeding and regular in size may be handled in pneumatic conveyors, which, because of their flexibility and elimination of dust, often are preferred to other means of transportation.

Of the so-called "mechanical" conveyors, four general types have been noted: (*a*) endless chain, (*b*) roller, (*c*) screw, and (*d*) reciprocat-

[1] Floating grain-transfer plants are used in some European ports which move wheat from the ship's hold and deposit it in barges alongside by pneumatic tubes at the rate of 250 tons per hour. As another example of unusual pneumatic service may be cited an installation which moved phosphate rock up to 1½ inch size through a hose at the rate of 30 tons per hour. (M. W. Potts, *Industrial Management*, January, 1924, p. 15.)

ing. The last named consists of a trough mounted in such a manner that it is given a rapid eccentric backward and forward motion, thus throwing the materials toward the point of discharge in a more or less constant stream. It is suitable for relatively short moves only and is most commonly used for handling sticky materials, such as raw sugar.

The screw conveyor consists of a "screw" which is designed to revolve in a tube or semicircular trough, thus providing the impulse which moves the material forward. This device will handle any bulk material up to 1 inch in size and has been successfully employed for horizontal movements, and even upon inclines not exceeding 20 degrees, for all distances up to approximately 300 feet. It delivers materials at a constant rate, and for that reason is often used in feeding machines such as are found in flour mills and cement plants, for example.

Roller conveyors consist of a series of parallel power-driven rollers which engage the commodity to be moved and carry it forward. This method of transport is rarely used save in steel rolling-mills, sawmills, and similar plants where heavy beams must be moved short distances over a definite route. It is particularly advantageous where reverse, as well as forward, movements are required.

The endless chain or belt, with its numerous specialized variations, is by far the most important type of conveyor. Such devices are equally serviceable for transporting materials of the fineness of flour or for coarse materials such as rock, coal, and iron ore. They are sometimes designed for operation on inclines as great as 45 degrees, and there are endless belt installations in use which are almost a quarter of a mile in length. They may be designed to operate under low temperatures, as in ice plants, or may be made to function equally well in annealing ovens and fire grates, where the temperatures approach the fusing-point of metal. For almost every type of service conveyors are available; and whenever the volume of work to be done is sufficient to justify a considerable investment in handling equipment, they provide an efficient and economical means of transportation.

A very significant advantage of conveyor transportation in the modern industrial plant is that it may be used to set the pace for the worker. The work is brought to the man in a constant stream, the rate of delivery being governed by the time required at each work place for performing the allotted task. Failure on the part of any workman to main-

tain his standard rate of performance is easily detected since his inefficiency almost immediately causes an interruption in the steady flow of work in process.

Thus, in the words of one authority, "The ability of conveyors to hold the output of a group of operators to a predetermined reasonable rate of production has favorably affected production costs, while reducing the unit cost of handling almost to the vanishing point."[1]

Relation of On-Plant to Off-Plant Transportation.—Sufficient attention has perhaps been given to the details of plant transportation equipment to indicate something of the complex and important rôle it plays in industrial operations. Transportation is an important factor in the operation of every manufacturing enterprise from the time the raw materials leave the hands of the vendor until the finished goods have been safely lodged with the consumer or intervening distributor to whom they are sold. There is, to be sure, an important break in this chain of material movements while the manufacturing processes are being performed; but progressive executives everywhere are realizing, as never before, the importance of reducing this enforced delay in the plant to a minimum as a means of promoting production economy and eliminating risk.[2]

In striving thus to shorten the production cycle, the remedy usually has been found in eliminating delays occurring between processing operations rather than in the processes themselves. Material movements have been speeded up both on and off the plant, and particularly at the "bulk-breaking" points in the receiving and shipping rooms where in-bound carriers give way to on-plant transportation equipment which in turn eventually delivers its burden to the out-bound carrier at the loading dock. Sometimes the same type of equipment is used for both movements, as where standard-gauge rail service forms a part of the inter-departmental transfer system or where trucks are used both

[1] *Report of the Materials Handling Division of the American Society of Mechanical Engineers, 1925.*

[2] Some astonishing achievements in the matter of reducing the length of the production cycle in which almost perfect co-ordination of off-plant and on-plant transportation has been an important factor may be cited. In the Ford industries, for instance, it is said to require often less than 100 hours from the time iron ore leaves the loading docks at Marquette until the finished car is in the hands of the dealer, this estimate allowing 48 hours for the ore movement by lake boat, 33 hours for the processing movement through the plant, and 15 hours for the shipping and handling of the finished car. Such precision necessitates almost continuous movement and perfect functioning of the transportation system.

between departments and for making off-plant deliveries of finished goods; but whether or not the equipment is thus used jointly, on-plant and off-plant material movements often have many points in common.

Organization for Plant Transportation Control.—This element of similarity in all transportation activities has led some students of organization to advocate that the entire problem of transportation, both on and off the plant, should be placed under unified control in a transportation or traffic department. In theory, at least, there is something to be said for this contention. All transportation deals with place utilities, and unified control does effectively provide for co-ordination between external and internal movements. In practice, however, this method of organization is seldom found. Off-plant transportation undoubtedly involves more than the interests of the production department; while on the other hand, material handling within the plant may be regarded as being primarily a production matter. If the latter activities are to be brought under a single control at all—say those who oppose completely centralized control—it should be in an internal transportation department the head of which is responsible to the production executive.

Still others, who no doubt have been much impressed by the problems of departmental foremen within the production department, insist that unified control even of internal transportation is impracticable; that each department should exercise the same authority over the use of its transportation equipment that it does over its processing equipment. The overhead cranes in an open-hearth or foundry department, or the conveyors in an assembly line, they insist, are as much a part of that department's equipment as the processing machinery. To introduce a division of authority serves but to multiply the difficulties of the departmental foreman who is in any event held responsible for results.

If we dismiss the first method which may, however, have much merit in certain situations, perhaps the issue may be somewhat clarified if a distinction is made between inter-departmental and intra-departmental transportation. There is little doubt but that the latter type of transportation under modern conditions has in many instances become closely identified with processing itself. Nothing is gained by removing this service from the jurisdiction of the departmental foreman. But it is undoubtedly true also, on the other hand, that control of inter-departmental movements may often be centralized to advantage. If, for ex-

ample, such movements are largely effected by trucks, a central plant transportation department may operate the equipment upon a fixed schedule, thereby adequately serving all departments and at the same time securing maximum productivity from the equipment which is assigned to the service.[1] Centralized responsibility for maintenance, repair, and recharging where storage-battery trucks are used, as well as centralized control over the truck personnel, promotes economy, and this appears to be sufficient justification for a plant transportation department having responsibility for inter-departmental movements. The advantages of centralized control are not so obvious, however, when the same equipment is used for both inter-departmental and intra-departmental movements.

No general plan of organization can be formulated which may be applied under all industrial conditions. Organization is, after all, merely a device for promoting economical operation, and here as elsewhere the nature of the device must be determined by the conditions under which it is employed.

[1] There is much difference of opinion as to the advisability of attempting to operate trucks on schedule even where a central plant transportation department is advocated. In one large plant, for example, it is claimed that it has been found much better for the plant transportation department to assign each truck to a given territory in the plant on the grounds of greater flexibility and less movement under partial load.

It should be remembered, of course, that where trucks are operated on schedule there is no reason why "floater" or "tramp" trucks may not also be provided which may be thrown in wherever a point of congestion arises. This is the same method which railways employ in the use of "extras" as a means of lightening the burden imposed on regular schedule trains.

CHAPTER VI

POWER PROVISION

Importance of a Correct Solution of the Power Problem.—Modern industry owes its very existence to the skill which man has acquired in providing and utilizing mechanical power. Without power the most elaborate machines would be inert and useless. Without it the control of working conditions, efficient lighting, and temperature regulation—all so important in the modern factory—would be impossible. Mechanical energy is employed in a number of ways in nearly every plant—for driving machines, for supplying heat to ovens, furnaces, and retorts, for refrigeration, for providing air pressure and water, and for heating, ventilating, and lighting the factory itself. All such services are derived either directly or indirectly from the power plant, and each must be carefully considered when means for providing power are being planned.

It should be noted that many of these services ordinarily are produced jointly, and indeed in many instances the production of one is largely incidental to the production of another. The same boilers may be used to generate steam for the engine-room and for processing departments where steam is required. Furthermore, only a fraction of the energy in the steam delivered to a turbine is utilized in turning its blades, and in many instances this partially spent steam is reused for driving auxiliary apparatus, operating heat processes, or providing warmth for the factory building. Under the circumstances, these auxiliary services may, in a sense, be said to cost little. Were they to be provided independently, however, their cost would be considerable and thus cannot be ignored by the manager who is attempting to discover the most economical means for providing for power needs as a whole.

Purchase versus Production of Power.—This condition of joint production of different types of power-plant service is sometimes the most important consideration when deciding whether to purchase or produce the energy required. Unless costs are correctly allocated to the various types of service, wrong conclusions are sometimes reached. This is well illustrated by the experience of a certain paper mill which requires

large quantities of steam in connection with the manufacturing process. Formerly, this plant produced its own power; and since exhaust steam, which otherwise would largely have been lost, was used by the processing departments, it was customary to charge all the costs of power-plant operation to the generation of electric current. This erroneous method of accounting made the cost of power appear to be 1.6 cents per kilowatt-hour. The local utility company offered to supply current for 1.3 cents per unit, and a contract was accordingly drawn up. When the production of power had been discontinued, however, it soon became apparent that the boilers still were required to provide the auxiliary services which hitherto had been ignored. Investigation followed, and it was found that if costs were correctly allocated, electric current could be produced for 0.86 cents per kilowatt-hour in the plant which had just been partially abandoned.[1] The loss incurred in this instance was caused by a rather obvious error in cost accounting which doubtless should have been detected before deciding to purchase power, but the incident serves to emphasize the fact that the operation of an isolated and relatively inefficient power-house may sometimes be justified when a variety of power services are produced jointly.

Where electric current only is required, the large central stations of public utility companies have demonstrated their superiority both in economy and reliability and tend to force the discontinuance of independent industrial power plants save where the latter are of sufficient size to create operating conditions resembling those of the central station.

There are several reasons why the industrial plant often can purchase power from the central station at less than the cost of producing it independently:

1. The mechanical efficiency of power-producing equipment varies in somewhat direct proportion with the capacity of the individual unit. With equally satisfactory operating conditions a 1,000 kilowatt turbogenerator, for example, will produce power at less cost per unit than will one of 100 kilowatt capacity.[2] In other words, the larger the mechanical unit the less the unit cost of the product.

[1] C. Vide, *Manufacturing Industries*, July, 1925, p. 39.

[2] Some readers may find it easier to visualize the capacity of power-producing equipment in terms of horse-power than in kilowatts. A five horse-power motor is approximately equivalent to 3¾ kilowatts, and, if operated continuously for eight hours, would require 40 horse-power-hours, or 29.8 kilowatt-hours (kw. hr.), of energy.

The practical significance of this well-known fact is seen in the rapid obsolescence of power-house equipment. Public utilities throughout their history have continually been faced by the necessity of installing larger, and hence more efficient, equipment as soon as it was available, until today the capacity of a single generating unit in many large central stations greatly exceeds the total requirements of most industrial plants.[1] Few manufacturing enterprises require sufficient power to justify the installation of the largest and most efficient type of equipment nor can they afford to assume the risks of obsolescence in the power plant which rapid development has entailed.

2. The diversity of load which the public utility has succeeded in securing by intensive merchandising methods can rarely be matched by the independent plant. Diversity means greater regularity of demand throughout the working day. And regularity of demand in turn means decreased average fixed charge per kilowatt-hour, a very significant fact since fixed charges represent one of the largest items in operating a power plant.

3. The central power station, because of its own vast resources and because it is often linked up with other central stations in a "superpower" system, is in a better position to insure reliability of service at

[1] This continual adjustment to rapidly changing conditions with which public utility companies have struggled in their effort to reduce operating costs is clearly indicated in the following statement by Samuel Insull:

"We then [1898] had in Chicago the marine type of steam engines with direct-connected dynamos in our Harrison Street station, using units as high as 5,000 horse-power, and were proudly confident that our production costs were below that of any other station of similar size in the country. That station has long since gone to the scrap pile. About 1900 we needed more generating capacity. The steam turbine had been receiving considerable attention. We were urged to install one of about 1,000 kilowatts capacity, the manufacturers hesitating to recommend a larger size. Late in 1901 we authorized the manufacturers to build for us the largest steam turbine they were willing to stand behind. The result was a 5,000 kilowatt unit which finally developed 7,800 kilowatts, put in operation in October, 1903.

"Five years ago we were installing turbo-generators of 30,000 kilowatts capacity. In our new Crawford Avenue station we now have two units of 50,000 kilowatts capacity each and one of 60,000. The next one, already ordered (the station is planned for at least eight units) will be 70,000 or 75,000 kilowatts capacity, and after that probably nothing under 100,000 kilowatts capacity will be installed."

Extract from a published address entitled *Looking Forward by Looking Backward*, delivered before the students of engineering at Purdue University, April 22, 1925. Four years after making this statement Mr. Insull installed a unit with a capacity of 205,000 kilowatts in one of his plants.

less cost than is an independent plant of limited resources.[1] Uninterrupted service in the isolated plant can only be insured by the installation of duplicate equipment which may be started when breakdowns occur; whereas the central station, by virtue of its association with other stations, can draw on them in case of emergency.

All of these circumstances give the public utility very real advantages in the economical production of power, but, of course, the possibility of purchasing power rather than producing it is predicated upon the presence of a utility company capable of rendering the service. Until our "superpower" systems are more fully developed, and as long as industries require steam as well as electric current, there will no doubt always be some plants which must produce at least a portion of their own power. It is the problem of this large, though rapidly decreasing, group of industries which will chiefly concern us in this chapter.

The Power Plant.—A discussion of industrial power would be incomplete without some consideration of the means commonly employed in its production. It must be realized, of course, that a comprehensive treatment of this aspect of the subject is beyond the scope of this study. In no department of an industrial plant are the problems of equipment design, selection, and operation more technical. At no point is the employment of specialized engineering talent more essential. But just as the business executive needs some legal knowledge, if for no other reason than that, as is often contended, it enables him to know when expert legal counsel is required, so also he needs some acquaintance with the nature of his power plant in order that he may fully appreciate the services rendered by his plant engineers and know when technical advice should be relied upon. If in the following pages but a scant introduction to this important subject can be given in plain non-technical terms, all will have been accomplished that was intended.

For convenience, power production may be considered under four main headings:

1. The boiler room, including fuel storage, preparation, and delivery to the boilers, feed-water provision, and steam generation.

[1] The advantage, from the standpoint of economy, which the central station gains through being linked with other central stations is strikingly illustrated by the experience of a certain large metropolitan hotel which installed its own modern power plant only to find that the local utility company could rent and operate these facilities in conjunction with its other stations and furnish the energy at less cost than if the plant were operated by the hotel management itself.

2. The engine room, including prime movers, generating apparatus, and necessary appurtenances such as condensers, circulating pumps, and the like.
3. Power transmission.
4. Auxiliary power-plant services, including provision of the plant water supply, air pressure, refrigeration, and factory heating, lighting, and ventilation.

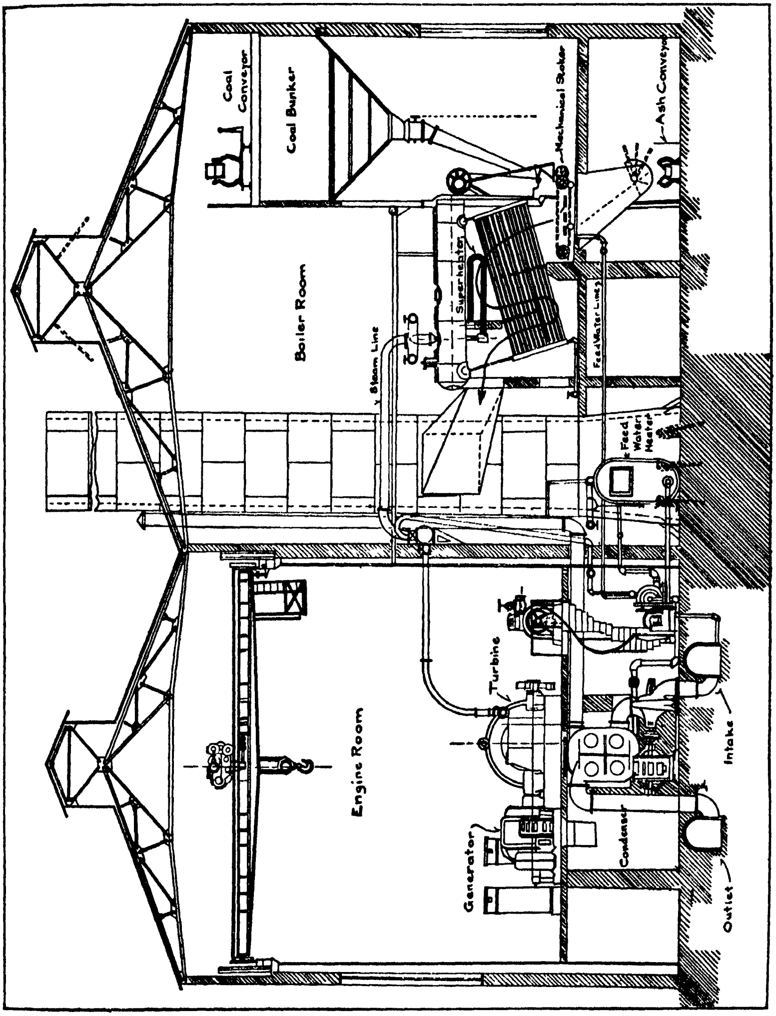
Some idea of the arrangement of a modern plant may be gained from Figure 5.

Boiler-Room Equipment.—Boilers which comprise the most important equipment in the boiler-room are merely specially designed tanks placed above a fuel-combustion chamber and arranged so as to provide a maximum of evaporating surface for the generation of steam under pressure.[1] Three general types are in common use: fire tube, water tube, and marine. The fire-tube type was the first to reach a high stage of development and, as the name implies, is so designed that the hot gases from the combustion chamber in passing to the chimney are forced through a series of tubes around which the boiler water circulates. Boilers of this type are seldom employed in modern industrial power plants except in small installations where low pressures are adequate and low first-cost is deemed more important than economy in operation. The water-tube boiler, which has in most plants supplanted the older fire-tube type, consists essentially of a series of tubes around which the hot gases pass. Its chief advantages lie in its ability to withstand high pressures[2] and its accessibility for repairs and cleaning. The marine type is merely an adaptation of the water-tube or fire-tube type, usually the latter, in which the combustion chamber is surrounded by a special water jacket so as to increase the heating surface and economize space.

[1] The provision of a boiler-room obviously presupposes a steam-operated plant. Internal combustion engines, particularly those of the Diesel type, are sometimes used. At present, they occupy such a minor position in American practice that they need scarcely be considered, though it is possible that they may be much more important in the small plant of the future.

[2] High pressures which increase the potential energy of the steam delivered to the transmission line are essential to operating economy. In this respect remarkable progress has been made. Only a few years ago a pressure of 200 pounds per square inch was unusual, but today from 600 to 700 pounds per square inch is commonly employed in large stations, and pressures of 1,000 pounds per square inch and upward are by no means a remote possibility. Not the least of the difficulties to be overcome in this technological progress is the development of materials which will withstand these enormous pressures under high temperatures.

There are, of course, many variations in the design of each of these general types for which the manufacturer in each case maintains more or less well-founded claims of superiority. All of these innovations have



Courtesy of H. R. Nissley

FIG. 5—Diagram showing typical arrangement of a modern steam power plant

as their purpose the increasing of steam-generating capacity either by securing more rapid and complete combustion of fuel or by better utilization of the energy thus released. The most important comparatively recent improvements in boiler design are:

1. Improved fire box design with a view to securing greater grate area and the introduction of mechanical stokers.
2. Introduction of artificial draft, thereby securing more rapid fuel combustion.
3. Introduction of auxiliary devices such as superheaters, economizers, and feed-water heaters, for reducing heat losses.

Mechanical Stoking.—Perfect combustion of fuel at a rapid rate is dependent, among other things, upon extensive grate areas and an even spread of fuel, both of which requisites have encouraged the introduction of mechanical stoking. In large modern boiler installations, hand firing would be physically impossible. At the same time, mechanical stokers give complete control over the rate of fuel consumption, insure complete combustion, and virtually eliminate manual labor in the boiler-room.

Various mechanical principles are employed in stoker design. One very common type is the horizontal chain grate which consists of an endless chain belt, the upper surface of which functions as the floor of the combustion chamber. In operation it is very simple. The fuel, after being crushed and wetted,[1] is carried either by inclined belt or vertical bucket conveyors to the top of the bunkers placed in the upper part of the boiler-house. From these the pulverized fuel flows by gravity to a mechanically operated distributor which spreads it in an even layer upon the charging end of the grate. The fuel is quickly burned as the grate moves forward, and the ash is carried over the farther end, where it is caught by a second conveyor and deposited at the end of the boiler-house. The rate of combustion is regulated by the depth of the fuel bed and the rate of travel of the conveyor, which factors are controlled either automatically or manually.

Draft regulation: The draft by which oxygen is admitted to the combustion chamber may be either natural, induced, or forced. Natural draft depends solely upon the height of the stack and fluctuating weather conditions, and for this reason is seldom used in modern plants, Induced draft is dependent upon the introduction of a steam jet or air current above the breeching in the stack, thereby inducing the draft

[1] Although increasing the risks of spontaneous combustion in storage and somewhat lessening the efficiency of the fuel, wetting is practiced as a means of preventing ignition of flying coal particles above the bunkers, preventing leakage through the grates, and reducing the tendency to clinker.

by creating a partial vacuum below. This principle is usually employed in locomotive design but is seldom used in stationary boilers. Modern plants usually employ what is known as "forced draft." This consists of a power-driven blower which introduces an air current under the grate. Accurate control of the combustion process irrespective of weather conditions is possible by this method.

Heat conservation: Equally essential to efficient boiler operation are the devices designed to make the best possible utilization of the heat generated in the combustion chamber. Feed-water heaters, which in some form have long been used, are designed to utilize the residual heat in the steam as it comes from the prime movers. This is forced into the feed water, thus raising the temperature of the latter before it is introduced in the boilers. From the feed-water heater, the boiler water passes to the "economizers" if economizers are provided, where the temperature is still further raised before entering the boiler proper. Economizers consist of a series of pipes located in the breeching of the stack, around which the hot gases from the combustion chamber must circulate on their upward path. Experience has shown that this device effects a considerable saving in fuel consumption, but more draft is required because of interference with the free passage of the chimney gases. From the economizers the feed water passes to the boiler itself, where the evaporation process is completed.

In the modern boiler the steam, before entering the transmission line, is passed through still another series of pipes called a "superheater," located in the direct path of the hot gases from the combustion chamber. Superheated steam, by virtue of its low moisture content and high temperature, greatly increases the efficiency of the prime movers.

All of these accessories of the modern boiler have done much to increase its capacity and improve its rating.[1]

[1] Since the matter of boiler ratings often proves confusing to the uninitiated, some explanation may be in order. At a meeting of mechanical engineers at the Philadelphia Centennial Exposition in 1876, it was decided to define "boiler horse-power" (b.h.-p.) as the boiler capacity required to deliver 30 pounds of steam per hour at a constant pressure of 100 pounds per square inch. To do this with the boilers then available, it was found necessary to have 10 square feet of heating surface; thus the rating of a boiler may be calculated by dividing the total heating surface by 10.

Modern boilers have been so much improved that for the same heating surface many times 30 pounds of water can be evaporated. Thus, when a boiler is said to be operated at 300 per cent rating, it simply means that it is capable of evaporating 90 pounds of water at 100 pounds pressure per boiler horse-power, or 30 pounds at a much higher pressure.

The Water Supply.—An adequate supply of pure water is of prime importance in the power plant. Impure water, when introduced in the boiler, creates certain chemical reactions which may cause foaming, incrustation, or excessive corrosion—sometimes all three at the same time. Foaming is due to the presence of alkali, which causes the precipitation of calcium and magnesium compounds carried in solution by the feed water. Such chemical reactions retard the evaporation process. Incrustation, commonly known as "scale," is the most common of all boiler troubles, and is caused by the presence of finely divided vegetable or organic matter which is carried in suspension or of other substances carried in solution, such as carbonate or sulphate of lime. Lime solutions are precipitated by the action of heat, thereby causing a hard porcelain-like incrustation on all inner surfaces of the boiler. Such deposits are a poor conductor of heat and thus result in a serious lowering of boiler efficiency. Corrosion is caused by the presence of some oxidizing agent, such as free acid, in the feed water, which, if not neutralized, results in the rapid destruction of the boiler.

When pure water is not obtainable, as is often the case in congested industrial districts,[1] the only remedy lies in treatment, which may consist of filtration, distillation, or chemical reaction, depending upon the difficulty to be corrected. In any event, it presents a problem for the chemist to solve. Condensers which are commonly employed in modern turbine-driven plants alleviate this difficulty inasmuch as they make possible the reusing of the feed water. On the other hand, the introduction of condensers presents another water problem of a different sort, since enormous quantities of cooling water are required for their efficient operation.[2]

[1] In industrial districts where boiler feed water must be drawn from open streams, a serious problem is often presented by the pollution of the supply by dye works, paper mills, chemical plants, and the like. Even rain water sometimes contains sulphuric acid in injurious quantities, by absorption from atmosphere which is heavily laden with sulphur fumes.

[2] A condenser consists of a series of pipes much like the boiler itself in construction, through which the exhausted steam is passed before being returned to the boiler by way of the feed-water heater for use again. The condensation is caused by a stream of cold water which is circulated around the pipes. By the condensation process a partial vacuum is created, thereby reducing the back pressure within the turbine, and feed water is conserved, although large quantities of water are required to operate the condenser itself. Modern plants require approximately 400 tons of water for this purpose for every ton of coal burned.

The Choice of Fuel.—The foregoing discussion has been predicated upon the assumption that coal was to be used as the source of energy. Coal is, of course, most commonly used, though there are plants which employ some substitute such as oil, gas, either natural or manufactured, or even wood, or other combustible waste which happens to be a by-product of the manufacturing process.[1]

Gas is a very efficient fuel, and is often employed when it is produced as a by-product of the plant, as in steel mills. In metropolitan districts also, where public utility companies are in a position to furnish the supply at reasonable cost, it is coming into somewhat general use, but is, of course, not available to many isolated plants. Fuel oil, likewise, has been widely used in certain localities. Like gas, it has many advantages from an operating standpoint when compared to coal, but except under special conditions, as when the plant is located near oil wells but far from coal-producing areas, can rarely be justified in point of economy. Until the technology of gas production reaches a much more advanced stage of development, or fuel oil can be produced at much lower cost than at present, it is likely that coal must continue to be the most economical type of industrial fuel.

Provision of an Adequate Fuel Supply.—Regardless of whether gas, oil, or coal is to be used, however, the importance of an adequate supply, both as to quantity and quality, can scarcely be overemphasized. Fuel is the raw material of the power department which, if not provided in ample amount, must inevitably lead to the shutting-down or restricting of plant operations. But as in the case of other raw materials, quality as well as quantity must be considered. As a leading authority has stated:

> The quality of coal is a most important factor of both the capacity and economy of a boiler. It is possible with a good free-burning coal to obtain from a given boiler twice as much steam as can be obtained with the same boiler and the same draft from poor coal, and the relative economy obtainable, or the steam generated per pound of coal, may differ 30 or 40 per cent.
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> The selection of the kind of coal to be used in any given boiler plant depends: (1) on the relative cost per ton of the different kinds delivered at the boiler; (2) on their relative total heating value per pound; (3) on the relative percentage of heating value which may be utilized in the boiler; (4) on the maximum capacity, or

[1] Sawmills, sugar mills, and steel mills, all commonly employ the combustible waste produced by the manufacturing process as fuel in the power plant. The presence of such by-products, which otherwise would be wasted, often is an important factor when determining whether such an industry should produce its own power.

horsepower, which may be developed by the boilers with different coals; (5) on the relative cost of handling the different coals and the ashes produced from them; and (6) on their relative smokelessness when used in the particular boilers and furnaces under consideration.[1]

With such a diversity of factors to be dealt with, the selection of the fuel to be used is by no means an easy task. Price quotations, chemical analysis, and the practical experience of the plant engineer, all must be consulted when drawing up fuel specifications.[2]

Smoke Elimination.—One important problem of coal-operated power plants which has attracted a great deal of attention in recent years is that of smoke elimination. As industrial districts have become more congested, the soot-laden atmosphere has come to be regarded as a menace to the community; and in certain cities drastic steps have been taken with a view to effecting improvement. Entirely aside from danger of becoming a public nuisance, however, the problem is worthy of the plant executive's close attention because the smoke emitted by his factory chimney is clear evidence that energy is being wasted. The presence of smoke indicates imperfect fuel combustion during which the "volatile matter" contained in the fuel is distilled but not burned. Valuable hydrocarbon compounds in consequence are carried off in the gases passing out of the stack and are lost.

Fortunately, improved boiler design, the introduction of devices for controlling the air supply, and automatic stokers, have practically solved this problem in the modern plant.[3]

Engine-Room Equipment.—The generation of electric current, which has become such an important aspect of power-plant operation, with

[1] W. Kent, *Steam Boiler Economy*, pp. 80 and 83.

[2] For a brief non-technical discussion of the problem of fuel specification and purchase, the reader is referred to W. N. Mitchell, *Purchasing*, pp. 65–70. A much more exhaustive treatment of this important subject is given in Kent, *op. cit.*, chaps. iii–v, inclusive.

[3] The economic significance of the smoke problem and its solution, which still occupies the attention of many municipal authorities, was never more clearly indicated than in a statement made years ago by William Kent:

"The greatest improvement which is to be made in average boiler practice is the adoption of furnaces for burning coal without smoke. In ordinary practice in the Western States an efficiency of 50 per cent or less is not uncommon, with coal burned in ordinary furnaces. It is quite possible to raise this to 70 or even 80 per cent with automatic stokers, furnaces surrounded by fire-brick, provision for securing the intimate admixture of very hot air with the distilled gases, and controlling the air supply in accordance with the indications of gas analysis. The raising of the efficiency of boilers by these means from 50 per cent to 75 per cent would effect a saving of many millions of dollars per year, and it would at the same time abolish the smoke nuisance." (Kent, *op. cit.* [1915 ed.], p. 709.)

the almost universal adoption of electric transmission lines and motors for distributing power in the plant, has made the generator, as well as the prime mover, an important adjunct of the engine-room. In modern practice these generators are almost always directly connected to the prime mover, sometimes through the medium of a reducing gear, thereby eliminating belt transmission with attending "slippage," high maintenance cost, and lowered operating efficiency.

As to the prime mover itself, the time-honored, slow-moving reciprocating engine with its ponderous size has almost entirely given way to the compact high-speed turbine. In its simplest form the turbine consists of a specially designed rotor inclosed within a metal shell. Steam is introduced at high velocity through a series of nozzles and impinges upon the blades of the rotor causing it to revolve. Compared with reciprocating engines, steam turbines require much smaller and cheaper foundations, occupy less floor space, require less attention, and, because no lubrication is required for any parts in contact with the steam, the exhaust steam may be reused in the feed water.[1] The highest superheats can be employed without affecting the choice of lubricants, and the cost of oil for lubrication is very low. The supremacy of the turbine thus clearly rests upon economy of investment and operation.[2]

Both direct-current and alternating-current generators are in common use, each possessing its own special sphere of usefulness. Direct-current generating equipment, as the name implies, is employed where direct current[3] is required, as in motor applications requiring speed con-

[1] J. A. Moyer, *Steam Turbines*, p. 1. The matter of superiority with respect to lubrication is of itself of considerable importance. The oil contained in the condensate of reciprocating engines must be removed if this is to be reintroduced in the feed water, since the presence of fatty acids in the boiler creates chemical reactions which are injurious to the exposed surfaces of the boiler.

[2] The relative cost of turbines and reciprocating engines in both these respects is indicated by the results of comparisons made by Mr. H. G. Stott, as quoted by Moyer, *ibid.*, pp. 384–85, as follows:

	Reciprocating Engines (Per Cent)	Steam Turbines (Per Cent)
Relative cost of maintenance and operation..........	100.00	86.03
Relative investment..............................	100.00	82.50

[3] Direct current is distinguished by the fact that it has a unidirectional flow as, for example, that drawn from storage batteries. Alternating current is that for which instantaneous values and direction of flow or polarity vary with time. Thus, in one cycle an al-

trol, for lifting magnets, and where current is used in electrochemical processes. With these exceptions, practically all modern industrial plants are equipped to employ alternating current. There are two reasons for this. First, alternating-current motors and generators are of less complicated construction, cost less, and demand less attention in operation than direct-current equipment designed for the same purpose. More important, however, is the fact that alternating current can be transformed from one voltage to another with less expense and loss of efficiency than is possible in the case of direct current. This is an important advantage where large amounts of energy are transmitted considerable distances, since energy losses in transmission are inversely proportional to the square of the voltage. Consequently, it is customary with alternating current to provide transformers which "step up" the voltage at the sending or generating end of the line and in turn "step down" the voltage again at the receiving or using end.

Power Transmission.—The electrical transmission of power has doubtless been one of the most important and revolutionizing innovations ever introduced in industrial plants. Before its development the only means of transmission available was by belt and line shafts. These were very wasteful of power, and indeed in a very real sense restricted the size of industrial plants. Under the circumstances, the purchase of power was impossible, and the plant itself could not be greatly expanded unless the power plant was entirely decentralized and prime movers were placed in each department where the power was needed.

Today two methods of electric power transmission are in common use: the gang motor drive and the individual motor drive. The first consists of employing a single large motor for driving a group of machines, as, for example, those within a single department. The motor by this method drives a line shaft from which the machines take power by belt transmission. The individual motor drive is characterized by the provision of a motor for each machine to which it is connected by means of a belt or gear.

Both plans have advantages and disadvantages. The first usually costs less in the beginning but is likely to prove uneconomical in operation. An elaborate installation of overhead shafting and belting is

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ternating current builds up in one direction to a maximum, subsides to zero, reverses, reaches a maximum in the opposite direction, and subsides to zero again. The number of such cycles which occur during a period of time is called the "frequency" of the current. Common frequencies are 25, 50, and 60 cycles per second.

necessary which is difficult to maintain in proper alignment and repair. Furthermore, as long as a single machine in the group is being operated, the entire line-shaft transmission system must be driven, a waste of power. For this reason, the gang motor drive is best suited for departments where all machines are normally under continuous operation, as in the loomroom of a textile factory.

If machines are operated independently and are subject to constant starting and stopping, as is often the case in machine-shops, for example, individual motor installations possess distinct superiority. The installation of individual motors requires a greater first outlay, but with the development of efficient small motors this method has come into much favor because of its greater flexibility in operation.

Auxiliary Power-Plant Services.—As indicated early in this chapter, there are many other services besides that of providing electric current for driving machines throughout the plant, which ordinarily are rendered by the power producing department. Such services include the following:

1. *The plant water supply:* Water is required by many manufacturing processes, as well as for fire protection and plant sanitation. In the isolated plant where a municipal water supply is not available, this service must usually be provided by a pumping plant in conjunction with the power-house, which is itself always a large user of water.

2. *Air pressure:* Wherever pneumatic machinery is employed, the necessary air-compressor equipment must, of course, be provided. In some plants compressors are located in the power plant, while in others they are located in the departments where the service is required, in the latter case being driven by motors which draw their power from the central plant.

3. *Heating:* Factory heating, as well as steam for processing when required, is usually provided from the central plant either by utilizing exhaust steam or by drawing directly from the boiler discharge lines.

4. *Lighting:* The provision of electric current for lighting is in every respect identical with the provision of current for power purposes. In that it often superimposes a fluctuating lighting load upon an otherwise fairly constant power load, however, it is likely to accentuate variations in power requirements. For this reason current for lighting is often procured from outside sources even where current for power is produced in the company's own plant.

5. *Refrigeration:* In many plants no refrigeration is required, while in others, such as meat-packing plants, it is by far the most important service performed by the power plant.

Measures of Power-Plant Efficiency.—From an operating point of view, the entire power plant may in many respects be regarded as a single machine, and as such its efficiency may be measured in the same terms as that of any other mechanical device. Fuel, the raw material, is introduced and is converted into power which is utilized at the drive wheels of power-driven tools located at various points throughout the plant. The efficiency of the power plant, therefore, is measured by the ratio between the energy applied (in this case in the form of raw fuel) and the energy actually made available for doing useful work.[1] In a mechanical process as complicated as that performed by the power plant as a whole, however, this measure alone is obviously inadequate. It indicates what is actually accomplished, but throws little light on why the results were what they were. Before intelligent supervision can be exercised, more detailed information is necessary. This has led to the development of certain plant operating ratios of proved value to those who are responsible for the results of power-plant operation.

Just as the financial executive may learn much by comparing his financial ratios for each period with similar ratios of past periods, and if possible with those of other companies in similar lines of business, so also the plant executive possesses somewhat similar standards which aid him in controlling his power costs. A suggestive list of such "operating ratios" follows:

1. *The average unit cost of power production* (usually expressed in cents per kilowatt-hour): The unit cost of production has always been regarded by business executives as one of the most useful measures of performance they possess, and doubtless they are right in this, providing a sufficiently elastic interpretation is given to the term "cost." A knowledge of departmental costs—and the cost of producing power obviously falls within this category—is useful for two reasons: (1) they provide a measure of the efficiency of the executive who is responsible for the departmental operations in question, and (2) they provide a

[1] This ratio, it will be recognized, is the measure of mechanical efficiency commonly applied to machines, that is,

$$\text{Mechanical Efficiency (expressed in per cent)} = \frac{\text{Energy utilized in performing useful work}}{\text{Energy actually applied}}$$

quantitative means of comparing the cost of operating a given department with the cost of procuring the service it supplies from some outside source.

In the power department both of these uses are of considerable importance. By comparing the cost of producing power with the cost in previous periods or with some preconceived standard, the trend with respect to the performance of the power plant personnel is indicated. The correctness of the inferences thus made depends, however, upon the degree to which variable elements over which power plant executives have no control are excluded from these costs. Likewise, power costs, when compared to the current market rate for power, throw much light upon the relative desirability of production versus purchase, though here again the trustworthiness of the conclusions depends upon whether the costs inevitably to be incurred in the abandonment of existing plant facilities have been duly weighed. Merely because a public utility company offers to supply power at less than the indicated cost of producing it in the prospective purchaser's own plant is obviously not of itself conclusive evidence that the production of power should be abandoned. Sometimes a number of power-plant services can be produced jointly much more economically than if one must be produced alone. Even when electric current chiefly is required, the costs incurred in connection with a power plant already in existence do not cease with the partial closing of the plant, and these "sunk"[1] costs may make it worth while to continue the production of power.

2. *The ratio between total power produced and total power required:* This computation indicates the relative importance of power production and power purchase. By its nature it is of significance only when the power plant is supplemented by an outside source. Its value lies in periodically bringing to the attention of executives the actual condition with respect to this important issue.

3. *The ratio between total power-house fuel cost and total power-house operating cost:* Fuel is one of the largest items included in variable power costs,[2] and in consequence is worthy of constant attention. The chief defect of this ratio is that it makes no attempt to distinguish be-

[1] This term is used by H. G. Brown, *Transportation Rates and Their Regulation*, pp. 11–12, and refers to those costs arising on account of an investment in a permanent and specialized plant which in consequence cannot be recovered by closing the plant.

[2] "Variable power costs" is used here in contradistinction to so-called "fixed costs," including interest charges and similar items.

tween variations in power-plant operating efficiency, variations in the quality of the fuel used, and variations caused merely by fluctuating price levels. Because of its mixed character, its chief value lies in the indication as to whether variations have occurred which should be further analyzed.

4. *The ratio between pounds of coal burned and pounds of feed water used:* This computation offers some indication of the efficiency of the boiler-room. Since it is expressed in physical terms, it is not influenced by price fluctuations. Such variations as do occur from period to period in a given plant may be traced to any one of three purely internal causes—usually in some measure to all three: (1) variations in boiler-room operating efficiency (largely a matter of supervision of personnel); (2) variations in the quality of fuel used; and (3) variations in boiler condition, such as the presence or absence of scale and foaming, which are traceable to the condition of the feed water.

5. *Pounds of fuel used per kilowatt-hour of energy produced:* This ratio is also expressed in physical terms and is influenced by conditions largely internal in character. It is of somewhat broader significance than the ratio last mentioned, however, since it involves the performance of the entire power plant.

6. *The ratio between total power-plant labor cost and total power-plant operating cost:* This ratio, when compared with those of past periods, provides some indication of labor efficiency in the power plant. Ratios of similar import can, of course, readily be computed for any element of operating cost.

7. *The ratio between total power cost and total manufacturing cost:* Although this computation is of little significance in measuring the performance of the power plant itself, it is of some interest in that it emphasizes the relative importance of the contribution made by power costs to manufacturing costs as a whole. Like all ratios expressed in financial terms, it is subject to the limitation that no distinction is made between variations due solely to changing price levels and those due to physical causes within the plant itself.

8. *Power used per factory worker or unit of goods produced:* This measure provides some indication of the relative efficiency of power utilization in the plant. It is essentially an average, of course, and in consequence is of little significance save where workers are employed at similar tasks and where all units of finished goods are identical.

9. *The ratio between total power consumed and total power-using capacity of the plant:* This measure pertains to the power-using departments in the plant rather than to the power plant itself, and provides some indication of the extent to which available power-driven equipment is being utilized. This ratio naturally will vary widely in different types of plants, often approaching unity where continuous processes are employed, and usually being much less than this in intermittent-process plants where the operation of one machine is not dependent upon simultaneous operation of other machines. In the latter type of plant, sometimes not more than 25 per cent of the power-driven equipment is normally under load at any given time.

10. *The ratio between actual power used and generating capacity required:* This ratio, commonly known as the "power factor" (p.f.), is defined by engineers as the ratio between real or active power and virtual or apparent power. Virtual power is measured by the product of volts times amperes (usually expressed in kilovolt-amperes or kv.a.). The capacity of generator equipment and transmission lines is expressed in terms of this unit. Actual power, on the other hand, is the amount of power used in the consumer's plant as indicated by his meter in kilowatts (kw.). Under some conditions, and with certain kinds of power-using equipment, a kilowatt is equivalent to a kilovolt-ampere, in which case the consumer's power factor is said to be unity. For some types of power-using equipment, however, this relationship does not hold, a kilovolt-ampere of generator capacity yielding something less than a kilowatt of power as indicated by the meter in the consumer's plant. Under these circumstances the consumer's power factor is less than unity.

The practical significance of this important ratio may best be explained by a concrete example. In Figure 6 are represented two power-users, A and B, each supplied from the central station, C. Each requires power at the rate of 100 kilowatts, but A's power factor is 100 per cent, or unity, while that of B is only 50 per cent. Under these conditions, A's requirements can be supplied by 100 kilovolt-amperes of generator capacity at the central station; whereas, in order to supply B's requirements, 200 kilovolt-amperes of generator capacity is required. This, in spite of the fact that the power consumption of both consumers, as indicated by their respective meters, is the same.

Obviously, this ratio is of considerable significance to the central

station which supplies the power, and accordingly the consumer with a low power factor ordinarily is penalized by having to pay a higher rate per kilowatt-hour for the power which he uses. Indeed, in some instances public utilities refuse altogether to supply a consumer with a low power factor until the condition is corrected.

It should be noted that a low power factor is the result of the type of equipment being used. It can be remedied by installing motor equipment designed to afford power-factor correction.[1]

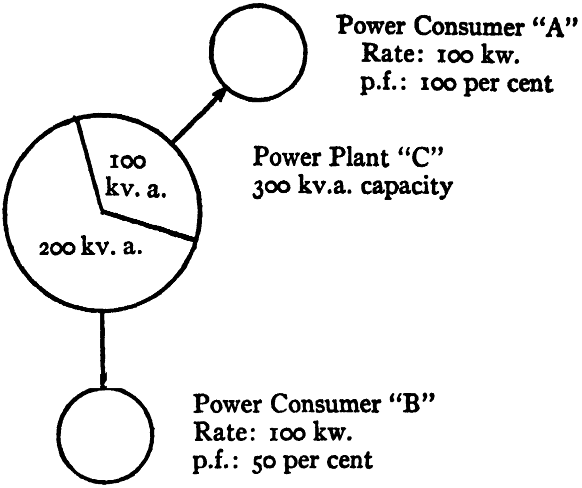


FIG. 6.—Diagram illustrating the significance of the power factor (p.f.) from point of view of the producing power plant.

11. *The ratio between average power load and maximum power load, commonly known as the "load factor"*: This ratio expresses what is probably the most serious problem of power-plant operation. Power must be produced at the moment it is required in the plant. Unlike raw materials, it cannot economically be stored, and hence the demands made upon the power plant fluctuate in direct proportion to the varia-

[1] The common induction motor has a low power factor, while the synchronous motor, a more recent development, has a high power factor, that is, one approaching or exceeding unity. Each type has its particular sphere of usefulness, however, and thus it is customary to install the latter type where it may be used, in order to neutralize the effect of the low power factor of the former, which is used where its particular operating characteristics are required. Another type of device, known as a "static condenser," serves a similar purpose and in consequence is sometimes used in conjunction with induction motors as a means of power-factor correction. The remedy to be applied where such a condition exists obviously must be left to the technical expert.

tions in the rate of power consumption. When this increases, more generator capacity is put in service; and when consumption falls off, the extra generator capacity required to carry the peak load stands idle. Interest charges continue, however, regardless of whether the equipment is running or not, and must be absorbed in the cost of the power actually produced.

The situation thus presented is indicated by Figure 7, which shows the typical daily load in one industrial power plant. It will be observed that the peak load representing the plant capacity which must be held

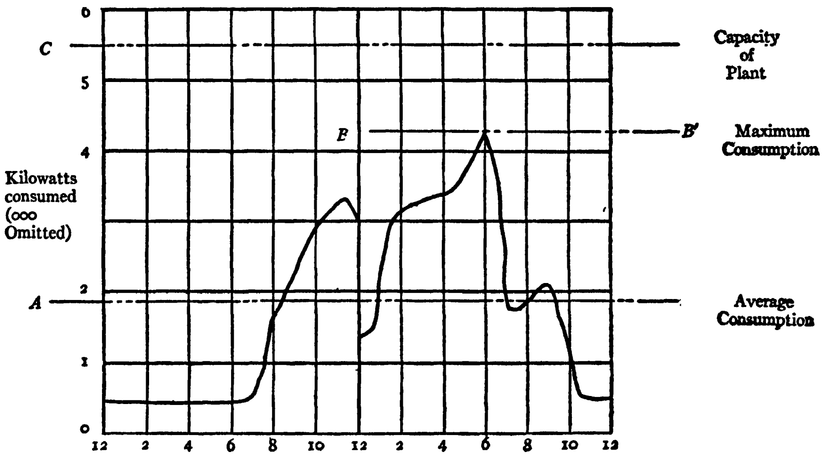


FIG. 7.—Diagram showing the typical daily-load curve in one industrial power plant

in readiness is approximately 130 per cent greater than would be required if the same amount of power could be produced at a constant rate as represented by the line AA'. Also, since this peak load is of relatively short duration, the power-producing capacity in excess of normal is in operation but a fraction of the time, thereby burdening the plant with a heavy idle-equipment charge.

Public utility companies, which, in common with all producers of power, must cope with this problem, attempt to solve it by diversifying their load. Consumers with varying demands are supplied from the same plant; the peak load of one customer comes at a time when the demands of another are slight; and thus the combined load is given some semblance of uniformity even though the individual loads fluctuate. But the remedy does not stop there. Central stations are combined

with other central stations with different load characteristics in a super-power system, all contributing to a common pool; and hence still greater diversity with its regularizing influence is enjoyed by all.

The isolated plant which serves a single factory cannot rely upon diversification as a means of regularizing its load unless it is in a position to combine forces with another plant possessing a load curve differing from its own, but it can often effect improvement by scheduling factory operations with a view to minimizing the peak demand.[1]

12. *The ratio between maximum power-plant capacity utilized and maximum power-plant capacity available:* This ratio, like the one just discussed, supplies a measure of unused power-plant capacity. It is of different significance, however, since the unused capacity which it measures is not caused by fluctuating power requirements but by the fact that the power plant has more capacity available than is used even by the peak load. The distinction thus made is illustrated in Figure 7, where the excess measured by this ratio is represented by the distance BC, whereas the unused capacity measured by the load factor is represented by the distance AB.

At first glance it may appear that this condition indicates merely that the power plant has been overbuilt because of failure accurately to estimate requirements, but such is not necessarily true. Excess capacity is often necessary as a means of insuring reliability in case of emergency as when breakdowns occur. Or again, it may have been deliberately provided in anticipation of increased power requirements in the future.

Clearly, either of these may be sufficient reason for providing excess power-plant capacity. Breakdowns in this department cannot always be avoided. When they do occur, the effect within the factory itself may be serious. Duplicate equipment is thus a form of insurance which may easily justify the added carrying charges. Again, if the saving effected in construction costs by deliberately planning for future requirements in advance is found to be sufficient to outweigh the carrying charges in the interim before it will actually be put in service, these carrying charges certainly cannot be said to represent waste.

[1] An interesting example of the possibility of correcting a poor load factor by combining forces with another plant is afforded by one large industry which has entered a mutually advantageous agreement with its local street-railway power plant. By this agreement it supplies power during the street-car rush hours which come at a time when its own power demands are slight, and in turn draws on the railway plant for the factory peak load which is required at times when traffic is light.

CHAPTER VII

CONTROL OF PLANT EXPENDITURES

Classification of Plant Assets.—The production manager, more than any other departmental executive in a manufacturing enterprise, is concerned with the custody, control, and use of fixed assets. Sales, accounting, finance, and personnel are essentially "office" departments. Their work place is the office, and their physical equipment is confined chiefly to the office and its furnishings. The work place of the production department, by way of contrast, is the plant, comprising all the different types of fixed assets which this term in its broadest sense denotes. The design, method of operation, and physical condition of these plant facilities in large measure determine the degree to which labor resources and raw materials can be utilized in the production of finished goods.

In the typical industrial plant this fixed investment includes the following:

1. Factory buildings and accessories
   a) Factory grounds and buildings
   b) Lighting, heating, and ventilating fixtures
   c) Elevator service
2. Fixed mechanical equipment
   a) Power-driven processing machinery
   b) Furnaces, ovens, boilers, and retorts
   c) Plant transportation equipment
3. Plant furnishings
   a) Benches, work tables, chairs, and miscellaneous fixtures
   b) Racks, bins, tanks, containers of all sorts
4. Tools
   a) Portable equipment, either power or hand driven
   b) Machine-tool accessories
   c) Gauges, measuring devices, and testing apparatus of various kinds

Analysis of the Problem.—The provision and control of this varied investment involves a number of considerations of fundamentally different character. It is axiomatic that plant investments must be justified by the extent to which they contribute to the business in hand,

that is, the production of finished goods of the desired quality and in such quantities as will yield the maximum net return. To be sure, some expenditures may more obviously contribute to the earning of profits for the enterprise than others. When the purchase and installation of a superior machine results in decreased production costs, for example, there is little difficulty in tracing the effect of the expenditure to the statement of earnings. Other expenditures, such as, for example, amounts spent in beautifying the factory grounds or providing more congenial and healthful surroundings for the working forces, may not immediately be reflected in increased earnings but are nevertheless to be justified, and presumably can be justified, by their ability in the long run to earn profits.

If all plant investments are to be subjected to this profit test, three things are essential:

1. All such expenditures must be accounted for in a manner which will insure that each accounting period shall be charged with its proper share of expenses, these to be allocated between periods in proportion to the benefits each receives. This is, of course, a problem for the accountant.
2. The physical assets selected must be capable of performing the required service. This, clearly, is an engineering problem.
3. The specific equipment selected must be that which will perform the required service at least ultimate cost. This involves a comparison of costs; it necessitates the adoption of a long-run view, and is essentially a problem in practical economics.

Capital versus Revenue: An Accounting Problem.—The first of these considerations raises the problem known to accountants by the term "capital versus revenue expenditures." The cost of all depreciating assets is in a very real sense merely a deferred charge to expense.[1] Plant assets are acquired not for their own sake but for the sake of the service they will perform during their useful life. Their initial cost, less any salvage or scrap value which may be recoverable at the end of their term of usefulness, is a part of the cost of that service. It is the problem of the accountant to distribute this among the intervening periods in proportion to their respective shares of the total service rendered. This is accomplished through the periodical estimate of depreciation expense. Thus the method of accounting for fixed assets hinges upon the

[1] R. B. Kester, *Accounting Theory and Practice*, II, 93.

question as to whether the service acquired when a specific asset is purchased will be rendered during a single accounting period or will continue through a number of periods. If the current period only receives benefit, obviously the expenditure may as well be charged to expense directly; but if succeeding periods also will be benefited, the expenditure constitutes a charge to an appropriate asset account and will subsequently be transferred to expense by periodical charges to depreciation.

The accounting theory thus stated is simple enough and presents no serious difficulties when additional assets are being purchased. It is not always so easy to apply, however, when alterations in existing facilities are being made. Under such circumstances, technical considerations often arise with which the production executive is more able to deal than is the accountant.

Suppose, by way of illustration, that in a machine-shop certain expenditures involving the replacement of parts of a machine tool are contemplated. The present machine, including installation, is carried in the books at cost less accumulated depreciation—$5,000. The alterations now to be made, let us say, will cost $900. The question then is, Shall this amount be charged directly to the expense of the current period, or shall the original value of the parts to be replaced, be written off, and the cost of the new parts set up in their place in the asset account?

According to accepted accounting practice, if these alteration costs are regarded as being simply *repairs*, they are proper charges to the expenses of the current period. But if, on the other hand, they are regarded as *renewals* constituting a betterment of the existing asset, a capital charge in the form of an adjustment of the Reserve for Depreciation and the Machinery accounts will be called for.[1] The second method of

[1] The terms "repairs" and "renewals" have a technical significance to the accountant which, according to A. Lowes Dickinson (*Accounting Practice and Procedure*, p. 163), is as follows:

"*Repairs*—This should include all current expenditures recurring from day to day and from month to month on the general upkeep of the existing property without the renewal of any substantial part thereof, and generally all periodic repairs which are necessarily undertaken within, say, one year. (This caption will, of course, include certain renewals of small parts, etc., such as would be necessary to continue the useful value of the unit of building, plant or machinery over the estimated period of its life.)

"*Renewals*—This should include all expenditures incurred in renewing in whole or in part, any unit of building, plant or machinery, which tend to extend its useful life beyond the average term. These expenditures would in general be those which would only occur at long intervals of two or three years, and whose effect would last for a number of years afterwards."

accounting would result in charging off the expenditure against the earnings of subsequent periods. Obviously, the decision made in such an instance will affect the costs of production during the current period and thus must be of considerable importance to the production manager.

As one recognized accounting authority[1] has said,

> In all cases of new construction and additions to the existing plant or equipment, no question arises as to the legitimacy of such capital charges. But when replacement, renewal, or betterment of existing properties takes place, difficulty is met in determining the portion chargeable to the asset and the portion chargeable against revenue. . . . The parts of a machine are subject to diminution in value due to wear, tear, and obsolescence, along with the machine as a whole. The machine was purchased for a lump sum. What portion of the cost is applicable to each individual part is difficult to determine and must usually rest on estimate or guess. Similarly, the book value, i.e., the present depreciated value of a part, is not accurately known. Accordingly, the amount of betterment, if any, in the replacing of an old part by a new part is difficult to determine. It is here that working rules must be adopted for each concern.

As examples of such working rules, it has been suggested that only when the renewal involves an expenditure of more than an arbitrarily chosen sum—say, $100—should there be any attempt to determine the amount of betterment, every expenditure under that sum being charged directly to expense regardless of the nature of the expenditure. In other instances it is customary to charge an expenditure to expense in all cases where it does not constitute a major renewal, i.e., more than 50 per cent of the entire asset unit. But what is the unit? Is the foundation, the frame, the flywheel, or the machine as a whole to be regarded as the unit? In the adoption of any such arbitrary rules, and even in their application, many technical questions arise concerning which the accountant must rely upon the advice and judgment of production executives.

Determination of Plant Needs: An Engineering Problem.—The problem of correctly accounting for plant expenditures obviously has a direct bearing upon the computation of the costs of production, and hence must be considered when budgeting production operations, plant additions, and maintenance. At best, however, it deals merely with the method of recording the results of a decision. To the production executive such considerations must always be secondary in importance to the

[1] R. B. Kester, *op. cit.*, pp. 89–91.

decision itself which involves the selection of proper plant facilities. The latter is strictly an engineering problem for which the production department must assume full responsibility.

The desirability of a manufacturing program or budget depends, first of all, upon whether the goods specified can be sold at a profit, and second, upon whether the plant is capable of producing these goods. Its preparation involves a continual weighing of possible income against necessary expense. Normally the first step in the formulation of such a program is the making of a sales budget—the estimated sources of income. But immediately the question arises as to how these sales orders are to be filled. Can the necessary goods be produced in the present plant? If so, how much will they cost? If not, what additional equipment will be necessary? How may the present plant be made more productive? How may the costs of production be lowered and a wider margin of profit be procured? Is the prospect of increasing sales temporary, or are expected increases likely to be permanent? Do they justify additional investments in fixed assets?

All such questions which naturally arise whenever future production operations are being planned lead directly to the main issue as to how the plant may be better adapted for the work in hand. It is this continual questioning and readiness to effect changes in the existing plant for which American manufacturers are noted that doubtless has been responsible for much of their success in recent years.

Standard versus Special Equipment.—The choice of factory equipment has become more and more involved, with the tendency in many industries to install specially designed tools for performing work which formerly would have been accomplished by machines of standard design. "Standard," as applied to mechanical equipment, is used to designate units designed for general or all-purpose service rather than for one specific task. Thus an ordinary engine lathe or milling machine, such as is described in the catalogues of all tool-builders, may readily be adjusted for a wide variety of work. Probably the needs of no particular shop were in the mind of the designer when such machines were being planned, but because of their general adaptability they function equally well in many shops and for many operations. "Special," on the other hand, is used in the sense of built-to-order, according to the purchaser's own specifications and with a specific task in mind. Special tools are not so versatile as those of standard design, but often will per-

form the single task for which they are intended more expeditiously than is possible with a standard tool.

By way of illustration, suppose that in a given shop one operation consists of turning a bar of steel 3 inches in diameter and 5 feet long. This is a job which an ordinary standard lathe may be "set up" to perform as well as many other operations. But suppose, further, that the required number of such bars is sufficient to require the full-time operation of the lathe. The question then arises as to whether a tool designed for this task alone will not do it better. If such a machine is chosen, the possibility of employing it on other tasks is precluded; but this disadvantage may be offset by its special aptitude for this one operation for which it is intended.

The choice thus presented merely introduces the problem of specialization in a new form, that is, specialization of machines rather than of workers. Both types of specialization are dependent upon the existence of a sufficient volume of work to justify employing a specialist for a single task, and accordingly specialization of workers and machines have frequently come about simultaneously. The chief advantages derived from specialization of workers are (*a*) the possibility of choosing a worker with peculiar adaptability for the task in hand, and (*b*) the ease with which he subsequently may be trained to perform a routine operation. Specialized machines, on the other hand, possess greater mechanical adaptability for a single task, thereby shifting more of the burden to the machine and making it possible to employ a less versatile attendant.

This is well illustrated by highly specialized (and in this case largely automatic) screw- and gear-cutting machines. Screws of any description may be cut on an ordinary lathe, but because of this tool's relatively poor adaptation for such work, a skilful machinist must be in attendance; whereas if the specialized machine is employed, an attendant of relatively little skill can operate a whole battery of machines, since nothing is required from him except keeping the tools supplied with raw material and disposing of the finished product.

There are, however, certain risks for both workers and machines which must be assumed—risks which seemingly are inherent in specialization. To the specialized machine-tender the risk of losing employment may sometimes seem more serious than to the versatile craftsman with a well-rounded training, since he has less to offer his employer and may

find more difficulty in finding another place where his peculiar skill can be utilized. But the very industrial setting which tends to make him a specialist also makes it possible for him quickly to acquire skill in a new job. It requires several years to train an all-round machinist, while in as many months a machine-tender can perhaps become as proficient as he ever will be in his own particular niche. The machinist, because of his varied training, can perhaps almost immediately adapt himself to conditions in any machine-shop; but so also can the less skilful machine-tender without much delay, for his specialized task is relatively simple and readily learned.

In contrast, a specialized machine can rarely be adapted to any work save that for which it was designed. If by reason of a change in the product or method of manufacture its function is no longer required, its utility disappears and it is forced into the discard. The danger of obsolescence is always imminent; and when eventually the specialized machine is superseded, it is likely to be of use to no one but the junk-dealer, whereas a standard machine often has a distinct secondhand value.

Obsolescence.—No industry has wholly escaped these risks of obsolescence with the constant urge to replace old but still physically sound equipment by newer, more efficient devices. Sailing vessels served their day and generation well but gave way before the superior advantages of steam-propelled ships, which in turn have become larger, speedier, more economical in operation, and more luxurious with each decade. Reciprocating steam engines have been supplanted in the power plant by turbines, which in turn have been improved so rapidly that prime movers seldom, if ever, are worn out when sent to the scrap pile. Textile mills, shoe factories, machine-tool shops, and steel mills—all have gone through similar experiences in varying degree. And more recently the development of the automobile, the radio, and the aeroplane can be traced in an endless succession of models which frequently have left in their wake the wreckage of the manufacturer's equipment, displaced but not worn out.

To the production executive this seemingly inevitable price of progress is continually presenting two important questions: (1) Has the time arrived for the substitution of a superior machine for the one now in service? (2) What are the probabilities of the new installation in turn becoming obsolete? These probabilities, as we have seen, are greatly

increased if the unit chosen is highly specialized, and thus an additional question may be asked: Do the superior economies of a special machine, as compared with one of standard design (assuming a special machine is available), justify any added risks of obsolescence which may be involved? If, for example, machine A of special design costs less to operate than the more versatile machine B of standard design, but is, on the other hand, more subject to obsolescence, choice must be made between readily computed immediate operating economies and the uncertainty as to what will prove to be economical in the long run. If the probability of obsolescence could be accurately measured, the relative merits of the two machines could readily be demonstrated, but unfortunately this is not always possible.

To reply to either of these questions that the decision must rest upon a comparison of costs is, in effect, merely to restate the original question, for the real difficulty lies in determining what the respective costs of the alternatives are. From the accounting point of view, no real distinction need be made between obsolescence and physical depreciation arising out of wear and tear, the passage of time, or the action of the elements. Both cause a decline in asset value which should be charged against the operations of the periods during which the decline occurred. If, for instance, a machine which normally would last ten years must, because of obsolescence, be discarded two years after it is installed, it makes little difference to the accountant why its value has so rapidly declined. To him the important thing is that its value has disappeared and must therefore be charged off as one of the costs of operation. If foreseen when the asset was purchased, the rate of depreciation would be based upon the actual life of two years; and these years which received the benefit of the service would properly bear the total burden. The very fact that it was foreseen when the asset was acquired justifies this procedure, for presumably it was then decided that, even in spite of imminent obsolescence, the service to be obtained in the meantime fully justified the expenditure.[1]

If, however, as is frequently the case, obsolescence could not have been, or at any rate was not, foreseen when the asset was installed, the rate of depreciation makes no allowance for it, and accordingly, when

[1] Many instances of this sort occurred during the war, when industries installed equipment for the manufacture of war materials. Often this was done with the full knowledge that the useful life of the machine was limited to the duration of the war, and it was accordingly depreciated on that basis.

obsolescence does occur, a considerable portion of the asset value still remains upon the books. The accountant who is interested merely in disposing of the remaining balance, may do one of two things: (*a*) he may charge the balance against the accumulation of past profits on the assumption that past periods alone have received benefit, or (*b*) he may carry it as a deferred charge to the expenses of future periods on the assumption that the change is being made to secure a future benefit.

But, irrespective of how the accountant clears his books of the remaining balance representing the book value of an obsolete asset, it is important to note that its value has in reality disappeared. It is irrecoverable in any event (save to the extent to which the obsolete asset possesses scrap or resale value) and should not be allowed to influence the decision as to whether or not the existing asset should be displaced by one of superior type.

The problem thus presented is an interesting and intensely practical one. Suppose, by way of illustration, that machine A now in use is physically sound and capable of continuing to perform its function for five more years. Machine B, however, is of superior type, and the question has arisen as to whether A should not be scrapped and B installed in its stead. The issue in the case is clearly defined, namely, By which method can the desired service be procured most economically during the remaining possible life of machine A? In making the comparison, the only value which can rightly be assigned to A is that which could be recovered if it were to be sold; and thus the cost of procuring the service by the two possible methods may be stated as follows:

Present Worth of the Service as Supplied by Machine A

The present worth of all additional outlays for operation, including costs of power, attendance, repairs, and maintenance, plus interest on scrap or recoverable value, but excluding depreciation and interest on present book value in excess of scrap or recoverable value.

Present Worth of the Service as Supplied by Machine B

The present worth of all outlays for operation, including costs of power, attendance, repairs, and maintenance during the period for which machine A might be continued in service, plus estimated depreciation of machine B and interest on the investment in B which might be postponed were A to be continued in service.

It follows, of course, that the scrapping of machine A can be justified whenever the cost of procuring the service (as defined in the foregoing

analysis) by the use of machine A is greater than by the use of machine B.

Provision for Future Growth.—A decision to acquire any fixed asset always involves the weighing of future possibilities. Funds once committed in the plant rarely can be recalled. As long as conditions remain stable, no difficulties are presented; but in alternate periods of expansion and contraction the plant is likely to be chronicly underbuilt or overbuilt. This condition is accentuated by the fact that industries often appear to possess a normal and fairly constant rate of growth; whereas plant additions can be made economically only in reasonably large units. The natural result is that the plant is operated in excess of its normal capacity until conditions become intolerable, when expansion is undertaken beyond present needs in order to be prepared for expected future increases. In the meantime, of course, the excess capacity is not utilized, but the carrying charges or "costs of idleness" are justified on the grounds that when it is needed it will be available at less cost than if an attempt were to be made to expand period by period as the needs of each required.

In reality, so many factors causing fluctuations in requirements are introduced that the general upward trend which is common to all successful enterprises is somewhat obscured; but it can nevertheless be discerned, providing a long enough period is examined. Some enterprising manufacturers have even conceived the idea of projecting their normal-growth curve into the future as a reference point for future plans and have consciously directed their efforts toward attaining this as their goal period by period.[1] That provision for future growth is an important aspect of the control of fixed assets is evidenced by the experience of all successful enterprises. Charles M. Schwab is credited with the statement that in all his years of experience in the steel industry he has never yet built a plant which was as large as subsequent events proved it should have been. This is merely another way of saying that the necessary expenditures for expansion could, in the light of subsequent developments, have been made more economically when the plant was first built, even though for a time a part of the plant would have remained idle. This is likely to be true, of course, only for

[1] In this connection a series of articles by J. H. Barber, "Forecasting Practices of the Walworth Company," published in *Management and Administration*, Vols. VII and IX (1924–25), are of interest. See also an article by R. B. Prescott, "What Progress Should a Firm Make?" *Manufacturing Industries*, Vol. XIII (April, 1927).

those assets which cannot be expanded economically as requirements increase. Thus, in public utility companies, which perhaps more than any other industry have been compelled to build in terms of the future the situation has often been met effectively by providing a building much in excess of present needs and by adding power-generating units only as the increasing demand for power developed.[1] The saving effected by erecting the building as a whole, rather than piecemeal as expansion becomes necessary, sometimes more than offsets the carrying charges of the unused floor space; but the same would not be true of the turbogenerator installations, which are accordingly deferred until actually needed.[2]

Comparison of Costs.—The propriety of any expenditure for fixed assets depends, first, upon whether the value assigned to the benefits derived from the acquisition exceeds the cost of securing these benefits, and second, upon whether this cost is less by the method proposed than by any alternate method.

To make the case concrete, suppose that in a certain plant a required service consists of delivering water at the rate of 100 gallons per minute at 50 pounds pressure. This service, let us assume, may be purchased from the local municipal water station at a given rate and hence has a definite and easily ascertainable market value. The first question is whether it shall be purchased or whether facilities shall be provided whereby it can be produced in the consumer's own plant. This can be answered only when it is known what it will cost to produce it. But suppose, still further, that several kinds of facilities may be used to supply the service. Both cylinder and rotary pumps of various kinds are available, all of which are mechanically capable of producing the service. The cost of the service, when procured by these different methods, must be computed in order to determine the minimum production cost which may in turn be compared with the market value of the service. But the situation may be still further complicated by future neces-

[1] The Waukegan plant of the Public Service Company of Northern Illinois is an example of a recent plant which was so planned. The turbogenerator room provided space for five units, which are being installed as the need for power increases.

[2] Doubtless, one important consideration in this particular industry is the rapid mechanical progress, and hence the serious obsolescence risks, with which public utilities contend. The building is not subject to rapid obsolescence as is the turbogenerator equipment. By deferring the purchase of the latter until actually needed, the most up-to-date machinery can be installed, and the inevitable obsolescence is by that much deferred.

sities. Suppose that it is to be expected that five years hence, long before the facilities required by the present service will have worn out, requirements will be twice as great as today. This clearly will have some bearing on the choice of present equipment though the problem is still essentially one of comparing costs.

The real difficulty lies not in comparing the costs of the various possible methods of securing the service but in placing the schedules of cost by the various methods upon a comparable basis. The purchase of an asset one, five, or ten years hence is not comparable with its purchase immediately. A dollar which one must spend five years from now obviously is not the equivalent of one which must be spent today. The respective costs of the alternatives cannot be compared until the present worth of the future expenditure is calculated.[1] Upkeep and operating expenditures for different assets obviously will differ in amount and will occur at different intervals, and before the respective schedules can be compared they must be converted to a present-worth basis.

The technique for choosing between possible fixed-asset expenditures may accordingly be stated as follows:

1. The analysis and specification of plant needs.
2. The listing of alternate plans for supplying those needs.
3. The preparation of schedules of expenditures involved in the alternatives, these schedules to include initial and all subsequent outlays requisite for securing the service.
4. The conversion of these schedules to a present worth basis, i.e., their restatement in comparable terms.
5. Selection of the plan to be followed which involves, in addition to the comparison of these schedules, the weighing of all intangible considerations not reflected by the cost comparison.[2]

As with all techniques, the results attained depend upon the character of the subject matter (in this case, the accuracy and sufficiency of the available data) and the judgment and ingenuity displayed in its use. At best, such an analysis scarcely can be expected to supply the

[1] The present worth of a future expenditure, x, is expressed by the compound interest formula: $\frac{x}{(1+r)^n}$, where r is the rate of interest which may be earned in the meantime and n is the number of years.

[2] For concrete illustrations of the application of this method the reader is referred to Mitchell, *Purchasing*, pp. 115–19. See also, E. L. Grant, *Principles of Engineering Economy*, and any standard work on actuarial science.

basis for decisions of greater accuracy than the data employed in making the analysis; but even at its worst, it is likely to be superior to blind guesswork and personal prejudice, upon which important decisions of this sort are not uncommonly based. Such an analysis provides no substitute for expert judgment but does afford a means of presenting the facts required in making an intelligent decision.

The Plant and Equipment Budget.—The enduring character and significant proportions of the plant investment and the relatively large amounts ordinarily contributed to production costs by depreciation and maintenance make it necessary for plant executives to anticipate and plan needed plant acquisitions as far in advance as possible. As a matter of fact, formal plant and equipment budgets were in fairly common use as control devices, especially in certain types of enterprises such as railroads and public utilities, long before budgetary control acquired the comprehensive meaning generally implied in the use of that term today. In organizations where budgeting has attained this broader significance, the plant and equipment estimates constitute but one important link in the budget system. But even where no complete system of budgetary control is employed, some form of plant and equipment budget is well nigh essential for controlling and maintaining the plant investment. In either case an adequate budget must supply information concerning the following: (*a*) the total estimated expenditures during the budget period for additions and proposed alterations in the plant investment, (*b*) the status of plant asset values at the end of the period after the completion of the proposed changes, and (*c*) the estimated charges to expense during the period for maintenance and depreciation of the plant.

The form in which this information can best be presented depends largely upon how it will be used in the individual enterprise. Figure 8 illustrates a suggestive budget summary in tabular form. In explanation of this form, columns 1 to 4 contain memoranda which can be taken directly from the plant ledger. Columns 5, 6, and 7 indicate the proposed changes in plant facilities and comprise the production executive's estimate as to what is required to place the plant in condition to fulfil all demands made upon it by the current production schedule. Columns 8 and 9 represent the method of accounting for the expenditures indicated in column 6. This information ordinarily is supplied by the accounting department in co-operation with the production or en-

gineering departments. Column 10 indicates the estimated depreciation charges during the period, which, when added to the amounts shown in column 9, represent the total charges to operating expense for the period as shown by column 11. Columns 12, 13, and 14 constitute a recapitulation of the proposed status at the end of the period. The first of these indicates the expected original book values after all adjustments for retirements and new capital charges have been made, and thus may be expressed as the sum of columns 2 and 8 minus column 5. Column 13 represents the sum of columns 3 and 10, while column 14 represents the difference between columns 12 and 13.

Procedure for Enforcing the Budget.—The immediate purpose of the plant and equipment budget is not entirely analogous to that of departmental operating budgets. The sales budget, the estimate of selling expenses, the production budget—all strictly departmental budgets in fact—are essentially forecasts of income or expense for the budget period. The plant and equipment budget, in contrast, deals primarily with the anticipated change of status of a certain group of fixed assets. Although its contents are directly related to the expenses of the current budget period, their influence is not necessarily confined to that period alone. Departmental operating budgets are accordingly usually prepared by months or similar short-time intervals in order that periodical "stock-takings" during the budget period may be facilitated. This method brings to light unsatisfactory tendencies with respect to current income and expense and permits of corrective action before it is too late. The plant and equipment budget, on the other hand, represents a plan of action which is not readily subjected to such minute subdivision. Fixed-asset alterations often are necessarily in process of construction for a considerable interval, and often little would be gained by attempting to forecast construction progress in the minute detail implied by monthly estimates. This budget may accordingly best be stated as a program for the entire budget period. It serves as a long-time plan, while current review of proposed monthly expenditures is insured by requiring the resubmission of projects appearing on the approved budget for authorization to proceed immediately before they are to be undertaken.

This budget thus functions as a preliminary survey of probable plant needs for the period. It is generally regarded as the maximum limit of fixed-asset expenditures during this interval, and therefore enables the

PLANT AND EQUIPMENT BUDGET

for the period beginning ______ and ending ______

(1) Group or Type of Asset	(2) Book Value at Beginning of Period	(3) Accumulated Depreciation at Beginning of Period	(4) Net Book Value at Beginning of Period	(5) Proposed Retirements during Period	(6) Proposed Expenditures during Period	(7) When Needed	(8) Estimated Capital Charges	(9) Estimated Expense Charges ("Repairs")	(10) Estimated Depreciation for Period	(11) Estimated Total Charges to Operation	(12) Estimated Book Value at End of Period	(13) Accumulated Depreciation at End of Period	(14) Estimated Net Book Value at End of Period

FIG. 8.—Summary of plant and equipment budget

financial department to proceed with its plans. For the production department, however, it is not necessarily the final word, since each project is subject to review and may be deferred when authority to proceed is requested if conditions have changed in the meantime.

Authorization of Expenditures.—Requests for authority to proceed with projects appearing on the approved budget properly originate with the production department, which was responsible for the preparation of the original budget estimates. A standard form is usually provided for this purpose, which includes a brief description of the project and the necessity for same, an accurate estimate of costs with the accounting distribution of these charges, and a comparison of these with the budget appropriation.

Responsibility for authorization generally rests with the general manager, though provision is often made, as a means of avoiding a tedious and unnecessary routine, whereby departmental executives may authorize minor expenditures included in the approved budget. Receipt of such authority is generally regarded as a prerequisite for issuing orders for the required materials and the negotiating of all contracts necessary for carrying out the project.

Control of Construction in Progress.—The purchase and installation of fixed assets give rise to some special problems with respect to their control during the course of construction. When the project involves merely the purchase and installation of a machine tool or other single asset, the problem of accounting for the acquisition is no more complex than for any other kind of purchase transaction. Upon receipt of authority for the purchase a requisition is issued; the order is placed; in due time the vendor's invoice is received; and finally, a voucher is prepared by the accounting department, designating the correct distribution of charges in its records, thus closing the transaction.

Many such projects, however, comprise more than a simple purchase transaction. A building, for example, is to be erected; the layout of the plant is to undergo extensive rearrangement; or an important program of renewals is contemplated. The entire program may be considered as a single project authorized as a unit, but its completion may require many months. It may be carried out by the company's own construction forces or may be the subject of an agreement with an outside contractor. In any case, it is likely to involve a long series of expenditures

extending through a number of accounting periods; and from the accountant's point of view it is desirable to segregate the costs in his records until the completed facilities are actually turned over to operation. Under such circumstances, it often is best to account for the entire project as a separate venture during construction, and a special account for the project is accordingly opened in the books of account. This is charged with all expenditures as they occur and is credited with

PLANT AND EQUIPMENT LEDGER

Machine No.	Name				Maker
Date purchased	Purchasing Price	Freight	Installation	Total Cost	Annual depreciation rate
Estimated life					Estimated salvage value

	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Depreciation charged off										
Book value to date										

Machine No.	Name				Maker
Date purchased	Purchasing Price	Freight	Installation	Total Cost	Annual Depreciation rate

FIG. 9.—Diagram showing the form of a useful plant and equipment ledger

all salvage values, and thus the balance shown by the account at any time indicates the degree of progress being made. Upon completion the project is "closed out" by transferring the net balance to the proper asset accounts in the general ledger.

The Record of Plant and Equipment Investments.—An accurate record of all asset values at the moment they are turned over to operation is, of course, essential since subsequent charges to depreciation are thereby determined. This usually entails maintaining a plant ledger in which accounts with all plant assets or groups of similar assets are shown. Al-

though in substance such a ledger is a subsidiary record showing in detail the balances appearing in controlling or summarizing accounts[1] in the general ledger, its form is not necessarily restricted to the traditional form of double-entry accounting records. A useful form of plant and equipment ledger which supplies the needs of both the accounting and production departments is illustrated in Figure 9.

[1] Typical general ledger accounts which customarily are supported by subsidiary records of this type are the Building account, Machinery and Equipment accounts, and their corresponding Reserve for Depreciation accounts.

MATERIALS CONTROL

CHAPTER VIII

STANDARDIZATION AND SIMPLIFICATION OF THE PRODUCT

Meaning and Scope of Product Standardization.—Standardization is one of the commonplaces of modern existence. On every side we hear of standardized commodities, standardized tools, standardized methods and procedures, standardized jobs, standardized records, forms, and nomenclature, and even standardized prices. To some methodical souls it is apparently the open-sesame to all material progress. Without it they see only chaos and anarchy which they abhor, and in consequence they insist upon order even at the risk of eliminating much of the variety of life. Others, in whom the individualistic spirit is strong, profess to see grave dangers in this pronounced tendency in the direction of uniformity even in physical things. It is but a short step, they say, from standardization of paving-bricks to "standardized hats, houses, and heads,"[1] and a standardized physical environment inevitably leads to deadened initiative. If these, indeed, be the alternatives, obviously standardization is not an unmixed blessing; but probably few will subscribe to the doctrine that unbridled diversity in all things is essential for the nurture of initiative and independence of thought. There must be some "golden *via media* between over-organization and under-organization—between standardization and anarchy" which can be found.[2]

The *International Dictionary* defines "standardization" as the act of reducing a thing to some accepted or established rule or model. Thus, by a standardized product, whether it be hats, steel rails, or wheelbarrows, is meant one that in certain respects conforms to some established and generally recognized type. Little is implied by this definition with respect to the standard save that it must possess some degree of permanence. To enjoy general acceptance, any standard must conform with certain flexible specifications. It must possess a certain degree of convenience, must be applicable to the subject matter in hand, and must have a recognized utility; but it does not necessarily need to be

[1] C. E. Russell, *Century*, May and June, 1926.

[2] S. Desmond, *North American Review*, June, 1926.

superior in these respects to other possible standards, nor does its origin need to have been more than pure accident.[1] The standard gauge of American railways is 4 feet 8½ inches, which is perhaps no better than 5 feet or 4 feet 6 inches would be; but the mere fact that the present standard was very early established and generally accepted precludes any possibility of change. Present standard sizes of hats, collars, and shoes, standard ratings of steam engines and electric motors, and standard dimensions of lumber or steel I-beams offer further illustrations of rather arbitrarily chosen specifications which are valuable chiefly because of their long standing and general acceptance. They serve as aids to communication and, in enabling buyer and seller, producer and consumer, or supervisor and worker, to speak the same language, prevent misunderstandings.[2]

But while general acceptance by all concerned is an essential characteristic of all standards, there are important differences which should be noted. In some instances a single standard is essential, whereas in others such limitations are obviously inadequate. The chief merit of the standard gauge for railways, already mentioned, lies in the fact that it is the only one employed. Diversity in such an instance would be objectionable. Even a poorly adapted standard, universally employed, would be vastly superior to the best possible standard not in general use. The efficiency of our railways depends upon interchangeability of rolling equipment. This so far outweighs any other consideration that a universal gauge is essential. No such necessity exists, however, with respect to standards of size for shoes or steel I-beams, for example, where, indeed, a sufficient degree of diversity to meet actual needs is of the utmost importance. Freight cars can be built to suit any practicable width of track, but the human foot which determines the size of a satisfactory shoe is of nature's making and is so variable that a single standard is inadequate.

[1] This statement is, of course, not true of all standards. Indeed, much of the interest in standardization in recent years has been directed toward the development of the best possible standards in a given situation. Perhaps it is this insistance upon the substitution of scientifically determined standards for those of accidental origin which is one of the most important contributions of Frederick Taylor and his followers, and obviously the value of standardization must necessarily depend upon the character of the standards used. See H. K. Hathaway, "Standards," *Bulletin of the Taylor Society*, Vol. V, No. 1 (February, 1920).

[2] P. G. Agnew, secretary of the American Engineering Standards Committee, *Annals of the Academy of Political and Social Society*, May, 1924, p. 270.

At the same time there are limits even to this diversity, and all essential differences may be accommodated by a limited number of sizes. If, to state the case concretely, the needs of all except a few isolated individuals were adequately supplied by twenty standard sizes of shoes, any additional numbers would likely be merely a source of expense to the producer and of no particular significance to the typical consumer. It appears that in this simple illustration is presented the most important consideration in product standardization and the justification for the current interest in simplification. The manufacturer is confronted by a given market, either already in existence when he entered the field or of his own making, which he desires to serve. It is his problem to adapt his product so that essential differences are recognized, but only those which his particular group of customers deems significant. Should he err in the direction of unnecessary diversity, it is at the risk of increased manufacturing costs without corresponding increases in the marketability of his product. On the other hand, undue simplification automatically restricts his market.

Kinds of Commodity Standards.—There are, of course, various bases upon which commodities may be classified. A given product may be brought into conformity with certain preconceived standards in some respects, and yet no two units may be identical. At least three different kinds of commodity standards need to be distinguished:[1]

1. *Standards of size or rating:* This type of standard may refer to dimension only as in the case of brick or shoes; to weight or volume as in the case of many packaged goods; or to rating or capacity as in the case of steam engines, freight cars, or motor trucks. The motive underlying the choice of all size standards is to provide the commodity in a form most convenient for the consumer's purpose. In practice the relation of the unit to the size designation often is purely nominal, the standard representing a means of identification rather than an indication as to the exact measurement of the commodity.

2. *Standards of design:* "Design," as here used, is practically synonymous with "style." In many instances these style variations are superficial, as in the case of the "finish" of a table or the color of an automobile. In other instances design standards involve something much more fundamental from the producer's point of view, as in the "cut" of a suit

[1] Compare this list with that suggested by Chase and Schlink, *New Republic*, February 23, 1927, pp. 12–25.

of clothes, the "weave" or "pattern" of a piece of cloth, or the "type" of a locomotive.

3. *Standards of quality:* The quality of a product is determined by the character of the materials entering its construction, the technique employed, and the precision or workmanship exercised in its manufacture. It is manifested in different ways with different products. In some instances quality standards are used to convey some idea as to the durability or longevity of the product. In others they provide a measure of the degree to which the commodity is capable of creating certain desired effects or reactions in use. Thus we speak of the "quality of a violin," meaning specifically its quality of tone; the "quality of a chemical product," by which we usually mean its purity; the "quality of a food product," by which may be meant flavor, color, odor, appearance, or wholesomeness; the "quality of a shoe," meaning largely appearance, durability, and accuracy of fit; and the "quality of a machine gear," meaning, perhaps, its relative strength, durability, finish, and precision of measurement. Because the criteria of quality vary with the product and in many instances do not readily adapt themselves to quantitative determination, standards of quality are the most elusive of all standards, being most difficult both to define and enforce. They are, in a sense, very closely related to both kinds of standards previously mentioned, since one of the determinants of the quality of many products is their degree of conformity with the standards of size and design which have been established. Size standards are necessary for their own sake in all repetitive manufacture. Yet at the same time conformity of the commodity with these size standards is a measure of quality. To be a quality product a shoe must be exactly like its mate or any other of the same size designation. The variation of a machine gear from its established standard of size must not exceed certain narrow limits. Even a paving-brick becomes a cull if much over or under size. The color of an automobile or a yard of cloth is a design consideration. Yet variation in the color may involve the matter of quality standards as well. The pattern of a piece of cloth represents a standard of design, but carelessness on the part of loom operator or supervisor may cause the product to be a "second," thereby in effect creating an additional standard of quality.

It should be noted that a product may be standardized in any or all of these respects. A brick manufacturer, for example, might decide to

produce both hard and soft burned brick—a quality consideration—in two standard sizes and five different colors or finishes. In all, he might have twenty standard varieties, the variations being due to different combinations of quality, size, and style. Or, he might adopt these standards with respect to, say, quality and size, but produce any color or finish desired by the customer, in which case his product would be standardized in some respects but unstandardized in others. No two orders might be identical, and yet in some respects he would have a simplified line of products.

The necessity for recognizing these different kinds of commodity standards is responsible for much of the diversity which is found in industry. If a shoe manufacturer, to refer to a former illustration, had no style problem, perhaps twenty or thirty models differentiated by size variations only would satisfy the major portion of his market.[1] But add to that fact the necessity of carrying practically all of these sizes in twenty or more different styles, and the number of needed variations becomes not twenty, but twenty times twenty, or four hundred. Likewise, some variations in quality may also seem desirable, thereby introducing still further diversity and complicating his problems of manufacturing and stockkeeping.

Product Standardization Not a Recent Innovation.—We are perhaps too much inclined to regard the standardization of products as a modern innovation, when, as a matter of fact, it is of very ancient origin. Bricks have been virtually standardized as to size for a thousand years at least. The standardization of shoe sizes dates back more than a century. The production of firearms, pins, nails, and clocks was partially standardized equally long ago. Few, if any, industries in their infancy have produced a standardized product, but they have almost invariably tended to do so during their course of development. The automobile, the typewriter, the radio, and the aeroplane are examples of modern products which in the beginning were entirely unstandardized, and have only recently emerged from the stage when each unit was a special job. In their march from this initial trial-and-error method of production to one of standardized product built entirely in anticipation of orders, they have but followed the path often traversed before by older industries.

[1] Existing size standards for shoes include approximately one hundred distinct variations, but a large proportion of these are required by relatively few users.

The initiative in this marked tendency toward standardization in nearly all lines of production has been taken by the producer rather than the consumer. Probably no consumer in the beginning ever insisted upon a standardized product, though in many instances he has, as the development progressed, come to realize that he, as well as the producer, gained something from standardization.

Relation of Product and Operation Standardization.—The advantages of product standardization are largely technological in character. Hence it is but natural that they should seem more important to the producer than to the consumer. The selection of raw materials, the character of the manufacturing facilities, and the methods of production are in large measure dependent upon the nature of the finished product, which must usually be standardized before standard materials, standard methods, and specially adapted equipment can be used. The standardized plant and methods of manufacture which are typical of the modern milling industry are possible only because the finished product itself is standardized. Take away existing standard specifications for automobile production, and present methods of manufacture would also have to be scrapped. The long assembly line with every product component exactly like its predecessor, coming always to its proper place in the line, and the entire process so well synchronized that finished cars are delivered to the storeroom or shipping dock with monotonous regularity, is dependent upon one condition, namely, each finished unit is exactly like every other. Introduce an important element of diversity in this product, and all the precision of operation is disrupted. The assembly line is no longer an organized unit, but a series of semi-independent jobs; and much of the skill acquired by the worker in performing some relatively simple operation over and over again is destroyed.

Some product variations are, of course, more disruptive in their influence upon manufacturing operations than others. The introduction of different colored bodies or different types of wheels makes little or no difference in the assembly of the finished car. This is because the effect of the variation has been localized in certain processing departments. The main assembly operation may still remain completely standardized, but the department manufacturing the part in which the variation has been introduced must accommodate itself to the change. Sometimes the necessary readjustment of operations to provide what

seem to be very important differences in the finished product are not at all serious. A clothing manufacturer, for example, may vary the pattern of the cloth he uses, or a knit goods manufacturer may employ many different colors of yarn, and thus secure considerable diversity in his finished product without introducing a single variation in his manufacturing procedure; but such possibilities are, after all, relatively rare in industry. The variations in the finished product in such instances are caused by variations in the raw materials as the manufacturer finds them, and not by anything he has done in his own shop. Wherever this is not true—and it never is where size and form differences are involved—the problem of finished-product variations ceases to be merely a raw-material purchasing problem and becomes a matter of vital concern to the production department.

In some instances, the most serious result entailed in changing the product is the necessity of making certain machine adjustments, with the attending loss of productive capacity while these alterations are being made. In others, product variations may even mean the procuring of new equipment and the scrapping of the facilities used in making the discarded model. In the manufacture of paper, for example, a change in the weight or width of the stock being manufactured involves the stopping of the paper-making machine (which in small mills comprises practically the entire plant) while the adjustment is being made. These changes, as it happens, are not difficult to make from a mechanical point of view, but do involve much loss of time and wasted materials before production can be gotten under way again. A shoe manufacturer, in deciding to introduce a new style or "last," must first provide himself with a new set of lasts in the entire range of sizes in which the new model is to be produced. If in a foundry the shape of a casting must be changed, a new pattern must be made. If in a steel rolling-mill a rail or structural shape of non-standard cross-section is to be made, a costly new set of rolls must first be procured. All of these examples serve but to illustrate the serious technological difficulties which often must be overcome in making what seem to be even minor changes in the finished product. Variations in the product are most serious in highly mechanized industries, since a machine is always less adaptable than a worker, but are always of some importance to the production department unless the variation can be effected merely by changing the raw materials.

Economies of Simplified Production.—As we have seen, diversity of product usually entails diversity in manufacturing operations. Hence it follows that from a purely production standpoint much is to be gained from simplification of stock lists. The manufacture of one thousand identical units of product, of whatever nature, is an entirely different matter than the production of one-tenth that number of each of ten different varieties. More specialized equipment may possibly be chosen. Fewer kinds of raw materials may be needed. Those required can be purchased in larger quantity. The total investment in inventories usually can be reduced. The manufacturing process is subject to fewer interruptions. The task assigned to each worker may be more specialized. In short, all the economies of specialization and large-scale production are in greater measure realized.

Advantages of Product Standardization to the Consumer.—These manufacturing economies of direct concern to the producer in turn seldom fail to lessen the cost of the product to the consumer. Many commodities which today are regarded almost as necessities—the automobile, the radio, and the electric light, for example—could scarcely have become so had standardized production not reduced the cost of manufacture to the point which brought them virtually within the reach of everyone.

But not the least of these advantages, entirely apart from the question of cost, is the fact that standardization enables the manufacturer to proceed in anticipation of orders. The consumer is not compelled to wait until the product he wants can be manufactured. He profits still further from the fact that the goods may be inspected in their finished form before actual selection is made. Sometimes this is just as important from the standpoint of securing service during the life of the goods as in making the original purchase. An important factor in the popularity of the Ford automobile has been the ease with which accessories and repair parts can be secured. All these are standardized and produced in anticipation of orders, and may be obtained as readily as the ubiquitous vehicle itself.

Reasons for Diversity in Manufacture.—In view of the technological and economical benefits to be derived from standardization and simplification, the question may well be asked as to why so much diversity is found in practice. That diversity in many lines of commodities in common use has been carried to great lengths must readily be apparent

even to a casual observer, and has been verified time and again by those who have been interested in the simplification movement.[1] There are, of course, two different angles from which this matter of diversity may be viewed. In the first place, there may be a great deal of variation in a line of commodities for an industry as a whole, and at the same time each producer within the industry may have a simplified line. Individual paper manufacturers, for example, might each produce relatively few grades of product. Yet, if each one's line was different from that of every other, the total number of varieties available would be very large. On the other hand, each producer may offer a widely diversified line of models or products.

From the standpoint of economical production, diversity of the first sort may conceivably have little significance merely because the economies of manufacturing a simplified line pertain to the individual plant, which, according to our assumptions, is confining its efforts to a limited number of products. The multiplicity of types offered in the market may indicate only that individual manufacturers have not co-operated in determining the maximum number of varieties needed to satisfy the existing demand. This absence of co-operation might be of little concern to a single manufacturer who fully recognized the advantages of simplification were it not for the fact that he is competing with other manufacturers who sometimes are able to convince the consumer that the distinctive properties of their products are significant. Such conditions must almost inevitably lead to the ultimate breaking-down of the individual manufacturer's system of standards and the introduction of diversity in order to meet competitors on their own ground. Thus, to be lasting in its effects, a program of commodity simplification must usually be acceptable to a sufficient number of competing producers to dominate the market.

The degree of diversity which is justifiable, economically or otherwise, in some products is greater than in others, however; and certain well-known instances of unstandardized production are not fully explained by the suggestion that producers have failed to co-operate in establishing standards. In many instances diversity is essential because of the peculiar use made of the commodity in question. As previously

[1] For citations of commodities where diversity has been very marked the reader is referred to the United States Bureau of Standard's publications with reference to simplified practice.

mentioned, the use made of some products is such that a single standard is well-nigh essential. The standard gauge of railways, already cited, standard spark plugs, electric-light sockets, and machine-screw threads are well-known examples of this kind. Diversity is intolerable from the consumer's standpoint, and producers have accordingly been quick to co-operate in establishing universal standards.

At the other extreme there are certain commodities for which exclusiveness is an important characteristic. All so-called "style" goods which are in some measure regarded by consumers as means of expressing individual taste are of this sort. Manufacturers of style goods are not likely to be impressed by the desirability of simplification when diversity is responsible for much of the value which their products possess. The same condition prevails with respect to another group of closely allied commodities not so much because of the style factor as because free play of the producer's initiative is an essential prerequisite of quality. No sensible person would advocate the standardization of oil paintings, fine furniture, or other objects of art, for example, simply because free play of the craftsman's imagination is necessary if the highest interests of art are to be served.

What should be guarded against is confusion of commodities of this kind with those of a more utilitarian nature, attempting to justify diversity as a point of merit when neither craving for exclusiveness nor inherent artistic qualifications demand it. Too often, diversity or lack of standardization must apparently be explained on just such grounds because exclusiveness has been used as a selling argument when there is no real need for exclusiveness. A sales strategy based on quality or price might, under the circumstances, better serve the interests of producer and consumer alike.

The Simplification Movement.—It was with a view to eliminating some of the wastes attending unstandardized production and, contrary to the contentions of some of its critics, apparently with sufficient appreciation of the necessary limitations of such a project that the United States Department of Commerce, under the leadership of Mr. Hoover, several years ago undertook to stimulate the interest of producers in product simplification. Although various scientific societies and the United States Bureau of Standards have long co-operated, with considerable success, in bringing about the elimination of unnecessary product types, the subject perhaps aroused little popular interest until the

war period, when all economy-promoting measures gained a welcome hearing. This initial enthusiasm, which, left to itself, would no doubt have been quickly dissipated with the return of peace, was organized and placed on a more lasting basis when in 1921 the Division of Simplified Practice of the Department of Commerce was formed for the expressed purpose of investigating "the existing diversity of common articles of trade and co-operating in plans for securing their simplification."[1]

In carrying out this purpose, the policies adopted have been so well advised and the success of the movement has been so marked that a brief summary of the methods employed by the Division is not amiss. Since lasting benefits must, in the final analysis, depend upon the co-operation of producers, distributors, and consumers, the Division wisely refrained from assuming the initiative in any specific simplification project and confined its efforts to providing the services and facilities of an impartial outside party. All such projects ordinarily originate with the interested parties themselves, being initiated by a letter of inquiry from a trade association, a manufacturer, or distributor. Letters are next sent to interested parties by the Division, with a request for an expression of opinion. If a sufficient number of favorable replies is received, a conference is called, usually resulting in the appointment of a committee to survey the situation and establish the facts. When this committee is ready to report, a general conference of representatives of manufacturers, distributors, and consumers[2] is called which considers the evidence and makes recommendations. These recommendations are, in turn, widely distributed among the three interested groups by the Division. If accepted by a sufficient number to represent the desires of those doing 80 per cent of the total volume of business for the commodity in question, they are published in the Division's "Elimination of Waste Series." Finally, the general conference appoints a permanent committee whose duty it is to secure adherence to the recommendations, receive criticisms, and arrange for constructive revisions from time to time.

The Limits of Profitable Simplification.—In inaugurating this procedure, it has wisely been recognized that to be of permanent worth any

[1] W. C. Wetherhill, "Elimination of Waste in Industry," *Journal of Franklin Institute*, July, 1926, pp. 1–22.

[2] The co-operation of consumers is, of course, possible only in the case of producers' goods where distribution is confined within practicable limits.

attempt to simplify products must be supported by the leading manufacturers in the industry, and, furthermore, that there are limits beyond which elimination of variety may prove undesirable. It is not difficult to demonstrate the possibility of reducing production costs by concentrating upon few products; but it is just as important for the producer to recognize that, if his line is too narrowly restricted, certain potential markets may not be tapped, thereby restricting the outlet for his product. This is especially true of style products. If, for example, the millinery trade could by some means be induced to concentrate its efforts on a limited number of standard models, there is little doubt but that the costs of hat production could be reduced. At the same time, one of the chief motives behind many of the typical consumer's purchases of this product would disappear. Sales resistance would undoubtedly be increased enormously, and the profits of the industry might not be as great as under unrestricted conditions. Products of this kind often are discarded by the user not because they are worn out but because styles have changed. The very life of the industry in its present proportions depends upon continually catering to this human craving for something new.

This is, to be sure, an extreme case, but it nevertheless illustrates a very important fact which many manufacturers must recognize. Goods are, after all, produced for consumers, and not consumers for goods. It is not the manufacturer's problem to produce goods at the lowest possible cost, but rather to produce those which the consumer wants at the lowest possible cost. Many industries can meet this requirement by offering relatively few models—in some instances, as previously cited, even one standard model will suffice; in others, extreme diversity must be the rule. Viewed from this angle, simplification is thus seen to be not simply a production problem but a marketing problem as well. It is not without good reason that the sponsors of the movement have proceeded on the theory that constructive recommendations in every industry must serve the best interests of producers, distributors, and consumers.

The Sphere of Unstandardized Production.—Recognition of the diverse needs of consumers as a group does not, of course, prevent each producer from attempting to supply the needs of a particular group of consumers, thereby simplifying his product. The fact that consumers' ideas of what constitutes a satisfactory automobile are of almost in-

finite variety has not prevented the Ford Motor Corporation from standardizing its product. In doing this, it has chosen to make its appeal to the large group of consumers who desire efficient and reliable transportation at the least possible cost. Other manufacturers, prompted by different motives, have aimed at a different sector of the market and have designed their product accordingly. Certain shoe manufacturers have committed themselves to the production of a conservative line with very few style variations, with a view of meeting the needs of those who demand serviceability rather than style. Others have chosen to serve that more fastidious but less numerous group of customers who demand style first of all. Large clothing manufacturers have standardized their lines and have made their appeal to the many who are satisfied with readymade clothes, but there is still room for many custom tailoring establishments which serve those who demand clothes made to their individual specifications.

The fact that often a large sector of the market is content with a standardized article is doubtless in some measure responsible for the growth of large enterprises which almost of necessity must standardize their products and methods of production. On the other hand, some part of the market, either by virtue of necessity or personal preference usually demands a specially built article, which explains why small manufacturers with unstandardized methods continue to thrive. Seldom can the latter hope to compete with the large enterprise on a price basis; but in their particular sector of the market they can, and do, justify their existence by offering certain valuable service considerations which the large enterprise with its standardized methods and impersonal outlook is unable to offer.

Securing the Advantages of Standardization with a Style Product.—In previous allusions to the style factor it has not been the intention to argue that the manufacture of style goods necessarily involves the employment of unstandardized methods. On the contrary, a manufacturer may establish standards of style just as he does standards of size or quality, but with this difference: style is more subject to change than either size or quality and must be more frequently adjusted to changing demand. There is little occasion, for instance, for periodically introducing new size standards for shoes. As the technique of shoe-making improves, new size standards and so-called "combination" lasts are sometimes introduced with a view to providing a better fitting product, but

with these exceptions the size standards of today probably conform very closely with those of twenty years ago. In contrast, style standards change every season, necessitating frequent readjustments in manufacturing operations. Fortunately, style changes often are not of very fundamental character and may be accomplished by relatively superficial readjustments, at most causing but temporary disruptions in operations.

If, when this transitional period arrives, previous standards are discarded as new styles are introduced, the presence of the style factor may not prevent the manufacturer from still confining his efforts to relatively few models. But if, as is frequently the case, conformity with style changes means adding new models without discarding the old, the situation is much more serious. The need for continuing to offer old models is not entirely fanciful, since in many industries style changes are the result of a gradual process. Some sectors of the market continue to demand the old model long after other sectors have discarded it in favor of the new. When this is true, a manufacturer, in attempting to meet the demands of the entire market, may readily be induced to add new models without corresponding eliminations. As a result he soon finds his efforts being spread over a diversified line of products.

It appears that the solution of this difficulty lies in a clear-cut determination of policy as to which sector of the market he is going to attempt to serve. The number of models required for satisfying this particular demand can then be determined. When new models must be introduced, a corresponding number of the least attractive old models may be discarded. The number of types at any given time will thus remain constant but will be the result of a succession of standards. Automobile manufacturers have, in many instances, solved the style problem in this way by introducing the well-known plan of annual models. The same methods are to be observed in more or less degree in all of the style trades. In none of these is standardization over a period of years to be thought of, but standardization at any given time is often possible and the difficulties of meeting this issue are localized in the relatively short time required to make the shift from one set of standards to another.

Standardization of Product Components.—Even in the transition from one set of standards to another, the change is often not as serious as appears on the surface. Style changes usually consist of changing some,

not all, of the components of the product. The production of those parts not involved in the change may continue without interruption from period to period. Parts standardization thus becomes one effective way of simplifying manufacture, particularly in assembly industries such as automobiles, locomotives, furniture, and shoes, even when the assembled product must be highly diversified. A certain manufacturer, for example, produces industrial locomotives always according to specifications supplied by the purchaser. Yet many finished parts are identical in all assembled units and the production of these is completely standardized. By such means many producers have found that, even while consumers' demands differ widely, standardization of many of the processes of manufacture is possible.

Responsibility for Product Standards.—The interests of all departments in a manufacturing enterprise are affected somewhat by the nature of the product. Until this product has been designed, raw materials cannot be purchased, methods of production cannot be determined, marketing strategy cannot be planned. Furthermore the establishing of product standards is not rendered less difficult by the fact that the interests of different departments sometimes appear to be in conflict. Simplification or elimination of product variations can scarcely fail to win the support of the purchasing and production departments, for it inevitably lightens their respective burdens; its benefits are not always so apparent to those who are responsible for distribution. From the production department's point of view, the ideal situation is always to manufacture a product with a minimum of variation. But the particular bias of this department needs the corrective influence exerted by the sales department, which is in touch with the consumer and recognizes the marketing difficulties which may arise from lack of diversification.

This conflict of interests is often more apparent than real, to be sure, but cannot be ignored in determining the policies with respect to product standards. Just as permanent results in simplifying the line of products in any industry must seemingly depend upon securing the co-operation of producers, distributors, and consumers, so also must product simplification in the individual enterprise be recognized as a problem requiring the co-operation of the manufacturing, purchasing, and selling departments. The actual work of preparing the designs for the product may be, and usually is, assigned to the designing department; but the adoption of standards, like so many other matters in-

volving the determination of policies, may properly be assigned to a committee composed of representatives from the interested departments. It is under just such circumstances, when differences of opinion must be reconciled and a meeting of minds must be achieved, that the committee as an organizational device justifies itself. When once the standards have been adopted and put in practice, responsibility for maintaining them may well be regarded as an inspection function, for which the inspection department should be held responsible.

CHAPTER IX

QUALITY CONTROL

Importance of Quality Standards.—Andrew Carnegie once said that "the surest foundation of a manufacturing concern is Quality. After that, and a long way after comes Cost."[1] In making this statement, which may well have disclosed the secret of his industrial success, he doubtless had no intention of minimizing the importance of low production costs. The costs of production must not, in the long run at least, exceed selling price. Low prices always have been and always will be one of the manufacturer's most effective competitive weapons. To the discerning consumer, however, price is meaningless except when associated with a given standard of quality. It is only by offering the same quality for less money or better quality for the same money that a manufacturer can demonstrate his superiority over competitors.

Adaptation of Quality to the Market.—"Quality involves a very definite specification of the important characteristics of the product which enable it to fulfill the needs and demands of the consumer in a satisfactory manner."[2] To do this it is not necessary, of course, for the manufacturer to strive for perfection. There are occasions, it is true, when nothing short of the highest attainable standards will suffice. Some instruments of precision, for example, must be practically flawless if they are to serve the purpose for which they are intended. The cost of production may, under the circumstances, become a minor consideration, allowing the manufacturer to proceed with no limitations save those imposed by his own plant and technical skill.

Ordinarily, however, the manufacturer labors under much more definite restrictions. The prospective purchaser must be convinced that the product possesses utility. It must be reliable. It must be durable over a reasonable period of time. It must be what it is represented to be. But above all, it must constitute the best value obtainable within the limits of price which the consumer is willing to pay.

[1] *Autobiography* (Houghton Mifflin Co., 1920), p. 123.

[2] G. S. Radford, *The Control of Quality in Manufacturing*, p. 26.

Requisites of Quality Control.—In order to meet these requirements and thus secure effective control of quality, it is necessary:

1. To define the standard of quality.
2. To provide the necessary facilities and organization for producing goods which conform with this standard.
3. To measure or compare the resulting product with the predetermined standard.
4. To provide the factory personnel with suitable incentives for the maintenance of quality.
5. To provide means for reclaiming goods which fall below the accepted standard.

Definition of the Standard: Quality Characteristics.—The standard by which quality is judged consists essentially of a list or specification of the characteristics which in the nature of things determine the service or satisfaction value of the product. These characteristics differ widely for different products and include such considerations as the following:

1. Dimensional accuracy—precision
2. Strength
3. Hardness
4. Fineness
5. Stability—ability to resist disintegration
6. Finish
7. Purity
8. Texture
9. Color
10. Flavor
11. Odor
12. Tone

All of these characteristics are, of course, not always of equal significance. The quality of a bar of steel, for instance, may be determined by the degree to which it conforms with certain specified dimensions, by its freedom from surface imperfections, by its ability to bear specified loads without excessive deformation, and by its resistance to wear. The quality of a carpet is determined by a different set of characteristics, including, possibly, coloring, uniformity of texture, and weight or thickness. The quality of a food product may be determined by such characteristics as flavor, odor, coloring, and freedom from impurities.

Furthermore, since, like all standards, the standard of quality serves as a measure or means of comparison for different units of the product,

its utility depends upon the degree to which it is possible to express these significant characteristics in quantitative terms. This can be done for some characteristics such as the "fineness" of flour and Portland cement, for example, which is readily expressed as the percentage of the sample being tested which will pass through a sieve of given mesh. The accuracy of dimension of a steel bar may be expressed as the allowable variation or tolerance[1] from a given standard of measure of known length. The strength or internal resistance of an I-beam under load can be resolved into its elementary stresses of tension, compression, and shear, which can be expressed quantitatively in pounds per square inch. The purity of a chemical or food product is readily ascertainable by quantitative analysis, and the desired texture of textile materials may be expressed in a certain number of threads per inch.

On the other hand, the most significant characteristics of quality for some products depend upon sensory impressions which can only with great difficulty be expressed in quantitative terms. The quality of such products can only be judged by comparison with some recognized sample. This is true of color, which is a quality characteristic of paints, dyes, and food products; of flavor, which is a quality characteristic of tea, coffee, and butter; of odor, which is a quality characteristic of many foods and of perfumes; or of tone, which is a measure of the quality of a musical instrument.

The practical distinction thus made is of considerable importance from the standpoint of inspection by which quality is maintained. Characteristics which may be expressed quantitatively are not dependent upon the permanence of some sample. Control can be made effective providing the inspector exercises reasonable care and accurate measuring instruments are used in making the test. The accuracy of the inspection obviously can be no greater than the accuracy of the measuring instruments employed. But assuming these to be correct, the procedure becomes somewhat impersonal and often requires little more than dexterity and a painstaking attitude on the part of the inspector. Where such quantitative measures are not available, quality

[1] "Tolerance" is defined as the allowable variation in size equal to the difference between the minimum and maximum limits. Thus a steel bar of 1 inch diameter with an allowable tolerance of plus or minus 0.001 inch might vary from 1.001 inch to 0.999 inch.

See "Progress Report of the Committee on Limits and Tolerances in Screw Thread Fits to the Council of the American Society of Mechanical Engineers," as published in the *Journal of the Americam Society of Mechanical Engineers*, in August, 1918.

control is less perfect, first because the sample with which comparison must be made is always subject to variation, and second because the accuracy of the comparison is more dependent upon the perceptive powers of the observer. It is possible that quantitative standards capable of being measured by instruments of precision will eventually be developed even for these characteristics. Until then, the degree of accuracy attained will depend almost entirely upon the personal qualifications of the inspector.[1]

Importance of Adequate Facilities for Quality Production.—Many factors may exert an influence upon the quality of the finished product. Ordinarily, the relation of one process to another is such that if an error occurs in one department, impairing the quality of the materials in process, it is impossible to repair the damage during subsequent operations; and to proceed without correction of the error results merely in accumulating charges on a product which must ultimately be rejected. To avoid such wasted effort, it is necessary, first, to provide facilities which are capable of producing the desired result, and second, to discover errors if and when they occur. Frequent inspections are necessary, accounting for the fact that in many plants inspection represents a considerable proportion of the total cost of production.[2]

The Choice of Raw Materials.—One of the most important factors in securing a uniform standard of quality in the finished product is the choice of proper materials. It is true that in some rare instances this factor is relegated to a position of secondary importance. The burning qualities of carbon monoxide gas, for example, are not dependent upon the quality of coal used as a raw material in its manufacture. High-grade refined sugar can be manufactured from beets or cane of relatively low sugar content. And by careful culling and matching, a high grade table might be made from lumber which, because of the presence of numerous imperfections, would not be given a high-quality rating.

[1] An interesting illustration of the dependence upon the personal skill of the inspector is afforded by the expert "taster" who is relied upon for judging the quality of tea, wines, and other beverages. While it is said that amazing ability is sometimes acquired by such experts, the limitations of the method in comparison with those used in judging dimensional accuracy, for instance, is apparent.

[2] Some idea of the importance of inspection as an element of production cost is given by the ratio of inspectors to total workers in typical industries. In the Elgin National Watch Company, for example, where extreme accuracy is essential, one worker in every eight is an inspector. In high-grade automobile work a ratio of from 1:10 to 1:20 is not unusual, while in foundry and general machine-shop practice one inspector to from twenty to fifty workers is usually found to be sufficient.

In such instances, which, after all, are comparatively rare and are confined to processes where crude raw materials are used, the standard of quality can be maintained by varying the production process. The quality of the raw material used is significant only in so far as it affects the relative costs of manufacture.

In most instances, and especially in all stages of manufacture where the original materials do not entirely lose their identity, there is a much more definite relation between raw material and finished goods. The quality of a ham depends almost as much upon the condition of the hog from which it was taken as upon the slaughtering and preserving processes. The properties of an automobile axle or a machine gear are determined by the properties possessed by the raw steel as much as by its treatment in the shop. High-grade woolen and cotton goods depend for their quality as much upon length and fineness of staple as upon subsequent workmanship. In all such instances, the control of quality must obviously originate in the purchasing department where the raw materials are selected, and the material specifications must not be in conflict with those established for the finished product.

Quality and Workmanship.—The importance of raw materials as a quality determinant always depends upon the degree to which deficiencies and lack of uniformity may be corrected within the plant. These plant operations constitute what is known as "workmanship," which exerts so important an influence upon quality that the two terms are often used as though they were synonymous. In the days of hand manufacture, from which we have inherited the term, "workmanship" was used to refer to the skill and patience of the individual craftsman and the degree to which he succeeded in impressing these personal qualities on his product. In the modern plant, workmanship no longer refers to the influence of a single worker, nor even to that of a number of co-operating workers, but rather to the influence of the plant as a whole, including the efforts of all the workers, the equipment which they use, and even the environment in which they work.

Influence of the Worker.—This transfer of the main burden of manufacturing from the worker to the machine has tended to lessen the influence of the individual upon quality. In operating an automatic gear-cutting machine or a printing press, for example, the actions of the worker have slight relation to the quality of performance so long as his machine is kept in adjustment. He functions, not by working on the product directly, but by keeping the machine oiled, repaired, and sup-

plied with raw materials. When these tasks are properly performed, the responsibility for quality is shifted to the machine.

In other operations where the machine is also virtually automatic, there are certain contingencies of operation which tend to throw more of the burden for quality maintenance upon the worker. In the operation of a modern loom, for example, little is required of the worker under normal conditions. If some contingency such as the breaking of a thread occurs, however, his services are immediately required, and carelessness in correcting the error cannot fail to react unfavorably upon the quality of the fabric.

The worker's responsibility for quality is, of course, most apparent in hand operations, for there are still many instances in industry where responsibility for correct performance rests upon the shoulders of the worker. In the manufacture of high-grade piano cases, no machine has yet been devised which can equal the human hand in giving a high polish to the product. Hand-sewed shoes and hand-carved furniture still maintain their superiority over the machine-made product, but only by virtue of the superior skill of the craftsman upon whom the hallmark of quality depends.

Importance of Proper Equipment.—But if, on the whole, the influence of the worker upon quality has under modern conditions become somewhat less, the importance of the equipment has increased. Equipment must, first of all, be correctly designed and constructed, but it is equally essential that it be kept in proper adjustment and repair. Rigid inspection and an effective repair and maintenance policy thus often become the most important links in the chain of precautionary measures by which quality is controlled. Nowhere is this more strikingly illustrated than in the manufacture of products for which precise dimensioning constitutes an important quality characteristic. The degree of accuracy which may be attained in turning a bar of steel, for example, was in part determined when the lathe which is used in doing the work was designed and made. But the capacity for accurate work in the best of machine tools depends upon frequent inspections and correction of maladjustments resulting from wear and tear. In performing this service, equipment inspection and maintenance forces are as much a part of the scheme of quality control as are the inspectors who are responsible for the acceptance or rejection of the finished product.

The importance of proper equipment is especially apparent in the

case of measuring instruments by which the dimensions of the product are determined. As has been said concerning such equipment,

> Their need springs from the desire for greater accuracy, which requires the use of something that is less subject to personal error and differences from individual to individual. This impersonal quality of the instrument flows from the fact that it is more positive in action than any unaided comparison by means of our senses can possibly be—a result that is accomplished ordinarily by enlarging or magnifying differences in reading, so that the errors may be detected with greater ease.[1]

The utility of instruments of precise measurement depends, however, upon their own freedom from error, for there is nothing so detrimental to quality as the spurious accuracy of a worker "who thinks he is doing accurate work because an inaccurate instrument says so." One common source of such errors is the confusion of mere "sensitivity" with "accuracy." An instrument may be capable of showing a change in reading for a very slight change in the thing being measured or in the conditions under which the measurement is being made, and thus be credited with greater accuracy than it possesses. On the other hand, it may lack sensitivity and still be very accurate. The test of its accuracy is, not how it happens to act in a given situation, but rather how its results compare with those of an instrument of known accuracy. Consequently it is necessary, where great precision is required, to be prepared "to check the work of all instruments by some superior method of measurement which is many times more accurate than the instrument which is being checked."

Relation of Working Conditions to Quality.—It should be noted that the performance both of workers and machines often is conditioned by the environment in which they operate; that working conditions, as well as the means by which the work is accomplished, may very greatly influence the quality of the resulting product. Man is a creature of his environment. He cannot normally be expected to take much pride in accomplishment if he is daily confronted on all sides by gloom, depression, and disorder. This environment may indeed prevent him from performing creditably even when he possesses the will to do so. Insufficient or poorly distributed factory illumination is the greatest enemy of quality when extreme care and concentration are demanded of the worker. Eye strain and poor ventilation hasten fatigue, with its accompanying increase in spoiled work which must be discarded at the

[1] G. S. Radford, *op. cit.*, pp. 217–23.

inspector's bench. Faulty atmospheric conditions may render the materials intractable and thus injure quality. Humidity, for example, is a prerequisite of quality in a woolen mill, but excessive humidity may be disastrous to quality in a woodworking plant.

Working conditions are perhaps most important as a quality factor when the materials in process are susceptible to damage by contamination. Flour, bread, dairy products, canned goods, and meat—in fact, all food products—are subject to taint. Consequently plant sanitation, personal cleanliness and health of the worker, and control of bacterial growth must be rigidly insured.

The Method of Manufacture.—The relation of the factors just considered to the quality of the product is readily descernible. Since they all pertain to different aspects of plant operation, and hence are subject to variation from day to day, the control of quality becomes largely a matter of controlling these factors.

Of equal importance as a quality determinant, however, is the method of manufacture. Different methods of doing things often lead to very different results. In order to maintain a certain standard of quality, it is necessary to exercise care in the choice of methods. As previously mentioned, there are some instances in industry where machine manufacture has never equaled the product of skilled handworkers. The distinction between a casting and a forging, which for many purposes of the machine-designer is significant, is a distinction arising from the methods of manufacture. The recognized superiority of open-hearth steel and of oak-tanned leather made by painstaking and time-consuming methods is but further evidence of the dependence of quality upon the method of manufacture.

Importance of Correct Supervision.—The method of manufacture must, nevertheless, not be confused with the degree of care exercised in applying the method. The open-hearth process of making steel may be a requisite for securing a desired result with a given quality of raw materials, but it does not insure these results. In order to impart certain desired properties to an automobile spring, the designer must perhaps specify a certain method of heat treatment; but the results actually secured will depend upon the care exercised in applying the method in the shop. Lax supervision may result in a low-grade product regardless of the method. On the other hand, the supervisor can scarcely be held responsible for better quality than the method which the designing or planning departments have specified is capable of producing.

Responsibility for Standards of Quality.—From the foregoing discussion of the factors of production which determine the quality of the resulting goods, it will be recognized that responsibility for maintaining quality rests squarely with production executives and must be shared jointly by the designing and operating departments. The former is responsible for planning the product, for preparing the specifications requisite for the desired standard of quality, and for designating the method of manufacture. In performing these tasks, it must work in co-operation with the marketing or selling department as well as with the operating or manufacturing departments which constitute the shop. For the standard of quality represents a conscious attempt to adapt the product to a given market and thus is intimately related to matters of marketing policy and sales strategy, for which the sales department assumes responsibility. At the same time, the standard must not be set at so high a level that it cannot be maintained within the practicable limits of manufacturing cost. The performance of all work according to standard is, of course, the responsibility of the operating departments in the shop.

The Need for Inspection.—It is the function of the inspection forces to determine whether the operating departments have assumed this responsibility. The immediate purpose of inspection is to detect errors with a view to preventing the completion and sale of goods which for some reason fall below the accepted standard. But the responsibilities of the inspection department do not cease here. Its sphere is to prevent errors, as well as to detect them. Its diagnosis must be sufficiently comprehensive to determine the cause of the error, to fix the responsibility where it rightfully belongs, and to suggest measures by which its recurrence may be avoided. In some well-managed plants its sphere extends even farther and comprises curative as well as preventive measures, in that the inspection department is given authority to decide what shall be done with substandard goods and control over the salvaging or reclamation departments.

Requisites for Effective Inspection.—There are certain important requisites which must be observed if this broad conception of the inspection function is to be realized:

1. Authority must be assigned in a manner which will insure independence of judgment on the part of inspectors.
2. All inspection activities must be co-ordinated and brought under unified control.

3. An efficient inspection personnel must be recruited and trained and adequate inspection equipment and facilities must be provided.
4. The methods and procedure of inspection must be adapted to the process or product being inspected.

Independence of Judgment.—The task of the inspector is judicial in character. It is true that little judgment is required where the unit of product clearly fails to conform with the standards which have been provided for the inspector's guidance. But where the product varies only slightly from the maximum or minimum limit, as is frequently the case when "high tolerances" must be observed or when it is impossible to set up any quantitative measure of the quality characteristic being judged, much depends upon the attitude of the inspector at the time. Indeed, in many such instances there are few units which may not be discarded upon some technicality, and frequent causes for dispute are likely to arise. It is important that the inspector be not unreasonable in the exercise of his function. It is equally important that he be saved the embarrassment of being required to pass upon work for which the executive to whom he reports is responsible. To subordinate inspection either to the engineering or operating departments is in effect to make these departments the judges of their own performance. Such practices must almost inevitably lead to undue lenience in censoring errors caused by faulty designing or lax performance in the shop. A much more desirable plan is to make the head of the inspection department directly responsible to the production manager. No one in the organization is more vitally interested in maintaining quality than the latter; and by causing the inspection forces to report directly to him, it is possible for him to keep in close touch with the performance of his subordinates.

The Co-ordination of Inspection.—As has previously been pointed out, quality control, to be effective, must originate much in advance of actual operations in the shop. Properly speaking, it begins with the selection of the raw materials, with the provision, maintenance, and adjustment of the manufacturing equipment, and with the control of working conditions in the plant. All of these contribute their share to the quality of the ultimate product. There is much similarity in purpose, if not indeed in method, in the inspection of raw materials, equipment, or working conditions and the inspection of work in process.

This suggests the possibility of creating an inspection department which is responsible for maintaining all plant operating standards which have a bearing upon the quality of the finished product. Centralized *performance* of all inspection operations is, of course, impossible. For that matter, centralized performance, even of materials-in-process inspections, is usually impractical unless they are confined to a single department such as the foundry, machine-shop, or assembly floor. Centralized *control* of all such activities is entirely possible, however, and much may be said in favor of the contention that all inspection activities throughout the plant have sufficient in common to justify the creation of a functional department of inspection as one of the major divisions of the production department.

The Inspection Personnel.—The selection and training of the personnel of the inspection department is one of the most important aspects of quality control. The qualifications of inspectors, especially if a high-grade product is to be manufactured, are more rigid than for any other type of factory worker. In the processing departments much has been accomplished in developing automatic and semi-automatic machines which do not require skilled attendance and which, indeed, in many instances have virtually eliminated the necessity for the exercise of judgment by the worker. There has been no comparable development of mechanical aids in performing the inspector's task. It is true that there has been much progress in this respect, particularly in the development of measuring devices. In fact, tolerances which today are commonplace in the manufacture of the moving parts of high-speed machinery would be entirely out of the question if the measurements had to be made with the relatively crude instruments of even a few years ago. But even these devices serve merely to sharpen the inspector's personal powers of observation. He still must exercise judgment. Whether a given unit of product shall be passed or rejected must be decided by him personally, for measuring devices, no matter how sensitive and accurate, are never automatic in operation.[1]

[1] Probably automobile manufacture, more than any other industry, has been responsible for the development of the extremely accurate measuring devices in common use in many inspection departments. The fact that reference gauges which are in constant use are subject to deterioration and must frequently be checked by gauges which are of necessity many times more accurate than the instrument being checked has made it necessary for inspection departments in plants carrying on interchangeable manufacturing operations to provide themselves with master-gauges used only as a "court of last appeal," and possessing a degree of accuracy which would have been unbelievable not many years ago.

In addition to this necessity for initiative, the inspector oftentimes must possess considerable technical skill, infinite patience, alertness, dexterity, and devotion to detail, for the task is usually a monotonous one. Such a combination of characteristics is difficult to find in one individual. Workers who take kindly to a monotonous routine often are deficient in other respects or tend to become careless in the humdrum of the daily task. The inspector often occupies a somewhat different position than the processing worker, in that errors during inspection may never come to light until the goods are in the hands of the consumer. Any tendency for the processing worker to slight his work is almost sure to be detected by the inspector, but the latter's own carelessness will not be discovered unless his work is in turn checked by other inspectors. Failure of the inspector of goods in process to detect substandard work will, of course, come to light in subsequent inspections. There is no check upon the work of the man making the final inspection. Ultimate control of quality may be said to rest in his hands.

Methods and Procedure of Inspection.—The relative importance of the inspection function depends, first, upon the number of inspections which it is necessary to perform, and second, upon the thoroughness with which each of these must be executed.

In nearly every plant it is necessary to make some sort of examination of the raw materials and of the finished product for the purpose of maintaining quality standards. In most plants, also, it is necessary to provide additional inspections of materials during the course of manufacture. Goods-in-process inspections serve a twofold purpose:

1. They aid in discovering hidden defects which might not be detected by inspection of the finished product.
2. They permit the detection of errors at the time of occurrence, thereby minimizing the losses resulting from further processing ot defective goods.

In most instances the second of these purposes is by far the most important, often requiring inspection and reinspection after each stage of the manufacturing process.

The thoroughness of inspections depends upon the nature of the commodity as well as the mode of manufacture. For some commodities and at some stages of the production process, inspection of judiciously chosen samples is sufficient. In other instances, much more thorough

examination, involving even 100 per cent inspection, is necessary. The theory underlying sampling is that the portions examined are typical of the whole. If the sample conforms with the standard, it is assumed that the entire product may be accepted. In the inspection of homogeneous, bulk materials, such as pig iron, cement, or flour, sampling is the only practicable method. Fortunately, also, for commodities of this type it is the average level of quality rather than the quality of the individual unit which is important. It is necessary, therefore, only that the samples shall be judiciously chosen and shall be truly representative of the product.

Often, however, it is not sufficient to be assured that the average of quality conforms with the accepted standard. Ball bearings, accurately fitted machine parts, gauges, and tools, for example, function as individual units. Failure of a single unit to conform with the accepted standard may constitute a serious defect and cause grave dissatisfaction on the part of the user of the assembled product. For such products, sampling is likely to prove inadequate unless one may safely assume that all units conform exactly with the sample. There are occasions, to be sure, when this latter assumption is justifiable. In highly mechanized processes, for instance, the quality of output depends chiefly upon the adjustment of the machine. If this adjustment is correct when operations are begun, and continues so throughout the "run," the product is bound to be of uniform quality, and it is unnecessary to resort to 100 per cent inspection to be assured of that fact. The initial and final portions of the "run" only need be inspected, since it may safely be assumed that the machine adjustments have undergone no change during the operation if the sample last chosen is of the desired quality.[1] This is true, of course, only when performance depends entirely upon the machine. Handwork is more subject to variation than machine-work and thus must be inspected with greater thoroughness if a high degree of uniformity is important.

[1] In some instances where extreme accuracy is required, 100 per cent inspection is necessary even under the conditions described above. Ball bearings, for example, such as are used in fine machine work, may be accepted if they conform with certain established tolerances; but it is important, nevertheless, that all balls assembled in a given bearing shall be exactly alike as to dimension. The inspector's task thus becomes not so much one of rejecting substandard units as of sorting those which are acceptable into groups of exactly identical units.

Fixing Responsibility for Failure.—The immediate purpose of inspection is to detect errors and thereby eliminate substandard goods, but

INSPECTION REPORT

Part No. ____________________ Ins. report No.__

Drawing No.____________________ Date ________

Operation No.____________________ Production order No.__

Location of work____________________________________

Foreman in charge____________________; No. in lot__

Accepted____________________; rejected ______

Reasons for rejection:

Faulty material__

Faulty workmanship__

Could fault have been detected in previous inspections?______

To whom should failure be reported so that it will not occur again?__

Description of fault:____________________________________

(To be supplied by Reclamation Department)

Can fault be corrected?____________________, Est. extra cost__

Disposition of rejected goods:____________________________________

*Signed:*____________________, *Inspector*

____________________, *Foreman Reclamation Department*

Fig. 10.—A form of inspection report used in a manufacturing plant

any adequate inspection system must go beyond this objective and trace the error to its source, with a view to avoiding its repetition in so far as is possible. The inspector need not always be on the lookout for

someone on whom to place the blame. Mistakes are inevitable. The possibility of friction between operating men and inspectors is great. Criticism is worthless unless it is constructive. Diagnosis is important only in pointing the way to curative measures, and to effect a cure often requires the utmost of co-operation by all concerned.

Figure 10 illustrates a form of inspection report used in a machine-shop, and suggests the type of information concerning rejected goods which inspectors may well be expected to supply to operating executives.

Incentives for Quality Production.—The attitude and inclinations of the men in the shop often comprise the most important factor in the control of quality. In consequence, much thought has been given to providing suitable incentives for quality production. Two general types of financial incentives of this sort are in fairly common use:

1. Those in which a penalty is imposed in case the workman fails to maintain the specified standard of quality.
2. Those in which extra compensation or a "quality bonus" is granted in case the standard is maintained.

The incentive value of the first plan is essentially dependent upon fear of punishment, whereas in the second it is the hope of reward for work well done which provides the needed stimulus. When stated in this fashion, many, no doubt, will insist that a bonus is superior to a penalty in incentive value. Particularly is this likely to be true when, as is sometimes the case, the penalty consists of exacting full compensation from the workman for losses resulting from his errors. Often there is little relation between the loss which management sustains and the ability of the workman to make good this loss. To exact full payment engenders a feeling of injustice which defeats the very purpose for which the penalty is presumably provided. It is the function of an incentive to prevent errors rather than to insure the employer against loss when errors occur; and if a penalty is to be employed for this purpose, it must be of such a character that it will have real incentive value.

Quality incentives need not, of course, be entirely financial in character. Quality production is, after all, a natural result of effective co-operation between employees and management. Any legitimate method of securing such co-operation is likely to have a beneficial effect upon quality of output. Educational campaigns and "propaganda," in the

best sense of that much misused term, for example, often have resulted in improved quality without resort to special pecuniary incentives.[1]

Reclamation of Damaged Goods.—The final step in the control of quality is the provision of adequate means for reclaiming substandard or rejected goods. The advisability of undertaking such salvage work must always depend on whether the extra costs incurred in righting the error are justifiable. Mistakes often may be corrected by slight effort, and, especially if many costs have already been accumulated, some means must be at hand to minimize the losses. Special care and highly skilled workers are essential for satisfactory reclamation work. In consequence a salvaging department, working under the supervision of the inspection department, has often been found to be the best way of meeting the issue.

[1] A notable case in point is the International Harvester Company. By an intelligently directed educational campaign this company has done much to improve the quality of its product as well as reduce the hazards of employment.

CHAPTER X

INVENTORY QUANTITY CONTROL

Nature and Scope of Factory Inventories.—Factory inventories include four distinct types of materials each representing a different stage in the manufacture of the product:

1. *Basic raw materials and supplies,* which will be consumed or transformed during the manufacturing process.
2. *Goods in process,* which consist of partially manufactured materials in the processing departments.
3. *Finished-parts stores,* which consist of purchased or processed components of the product temporarily held in storage subject to withdrawal by the assembly department.
4. *Finished merchandise,* which is held subject to the demands of the shipping department.

In many industries, such as flour-milling, cement manufacture, and steel production, for example, no assembly operations are required and hence no part of the inventory investment consists of "Finished Parts." On the other hand, assembled products, such as automobiles and machine tools, for example, are composed of many separate and distinct parts. These components may be compactly stored, whereas the assembled product often is bulky and requires much space in the storeroom. In consequence, a distinct break in the manufacturing process usually occurs prior to the assembling operations. Raw materials are issued to processing departments where the components are manufactured. These parts are then sent to storage, where they remain until withdrawn by the assembly department only as the assembled goods are required for filling sales orders.

Factors Determining the Size of Inventory.—The amount invested in raw-material inventories depends upon the degree of co-ordination between purchases and production, which is largely determined by purchasing policy. If materials are bought only as required by the production department, the inventory investment is reduced. This policy of "hand-to-mouth" buying may, however, increase the cost of buying and thereby more than offset the savings effected by carrying smaller inventories.

In contrast, the amount invested in finished-goods inventories is determined by the degree of co-ordination existing between production and sales. It is not always possible to produce goods at the moment they are required for filling sales orders. Often, sales are highly seasonal. It is estimated that 75 per cent of the annual sales in the wall-paper industry, to cite an extreme case, occur in the three spring months. The sales of some divisions of the agricultural-machinery industry are nearly as seasonal, and many luxury-producing industries sell a large proportion of their goods during the month or two preceding the Christmas holidays. As Professor Clark has pointed out, these seasonal fluctuations in demand are usually "the joint effect of several causes, such as a combination of climate and custom,"[1] which a manufacturer is unable to alter.

Yet, if he were to attempt to produce only when there was a demand for his product, the result often would be industrial suicide. A factory organization cannot be built in a day. To maintain an efficient working force and secure a reasonable return from a large plant investment, some degree of regularity in production operations is well-nigh essential. In the seasonal industry it is usually necessary, therefore, to manufacture for stock when sales are depressed, thereby carrying current operating investments in the form of finished-goods inventories until the selling season arrives.

Just the reverse of this situation is experienced by some manufacturers who employ perishable materials. In the canning industry, for example, the raw-material supply must be acquired during the harvesting season. Spoilage of the highly perishable materials must be prevented by immediate processing. Large stocks of finished merchandise are thus accumulated in anticipation of sales which occur at a fairly constant rate throughout the year.

In intermittent-process industries, such as steel rolling-mills, plants manufacturing plumbing supplies, and jobbing foundries, which produce a large number of standard products on a job-order basis, a large investment in finished goods is necessary because orders for considerable amounts must be placed in process if the goods are to be produced at reasonable cost. Certain preparatory operations, such as issuing orders, setting up and adjusting machines, requisitioning tools, instructing the worker, and preparing reports and cost records, must be per-

[1] J. M. Clark, *Studies in the Economics of Overhead Costs*, p. 154.

formed but once for each order, and give rise to costs which remain fairly constant regardless of the size of the order placed in process. In many instances it is uneconomical to produce a small order such as might satisfy all immediate needs for the article in question, because of these fixed charges. Thus an order is initiated for more than is immediately required. In deciding how much to produce, an attempt is made to balance these fixed charges against the costs of carrying larger inventories necessarily incurred if the size of the individual order is increased. The most economical quantity to manufacture is thereby determined, and this becomes the standard ordering quantity for the commodity in question.

The amount of goods-in-process inventories is practically determined by the length of the production period. Industries such as bakeries, paper mills, ice-cream factories, and fruit and vegetable canneries, for example, which normally have a very short production period, rarely have much goods in the processing departments, for it is almost immediately converted into finished goods. The situation is entirely different in a tannery, where the production period is of several months' duration, or in piano and watch factories, where raw materials are put in process almost a year before the products are completed and ready for sale. The only practical method of effecting a reduction in process-inventory investments in industries of this type is to devise some means of shortening the production period.

Objectives of Inventory Control.—Inventory control involves two distinct problems:

1. The management must be assured that inventory investments are no greater than they should be.
2. Inventories must be conserved and utilized in the most efficient manner.

Inventory investments can be justified only on the grounds that they make it possible for the enterprise to function more efficiently than it could without such investments. Any increase in this investment which results in savings of sufficient amount to offset the added carrying charges, and thereby causes a reduction in operating costs, may be said to be truly productive. Where no such net savings can be shown, obviously the added investment is non-productive.

The second problem involves the prevention of misappropriation, avoidable losses, and waste. Inventories, as well as cash, must be sur-

rounded by proper safeguards in order to insure that they shall be used for the purpose for which they were acquired.

Essential Features of an Effective Inventory Control System.—To accomplish these objectives it is necessary:

1. To formulate a comprehensive inventory budget.
2. To devise procedures for handling routine inventory transactions.
3. To provide means for securing a thorough analysis and evaluation of results for the purpose of measuring the performance of responsible departments.

The Inventory Budgets.—Inventory control is very closely related to the activities of the purchasing, production, and selling departments. Purchasing and production operations are affected by prospective sales, since the object of a business enterprise is to make a profit, and unless goods are sold no profits are realized. Considerable time is required to purchase and secure delivery of raw materials and to convert them into finished goods, and thus it becomes necessary to anticipate the needs of the sales department. In some industries with a short production period, plans for providing these goods need not be made in detail for more than a day or two in advance. In many instances, however, purchasing and production operations must be planned for several months in advance.

In preparing these plans, it is customary first to construct a sales estimate or budget. From this, finished-goods requirements are readily ascertained, and a production budget is prepared. The production budget in turn supplies the information which is required for estimating raw material needs and constructing a purchasing budget. These budgets are necessary:

1. In order that the production and purchasing departments may make plans by which finished goods and raw materials will be made available as needed.
2. In order that the financial executives may be informed as to the probable financial requirements of the proposed operations of the sales, production, and purchasing departments.
3. In order that the most economical inventory investments may be ascertained.

The amounts of finished goods and raw materials on hand usually are subject to daily fluctuations since it is the function of inventories to take up the slack between sales and production, and production and

purchases, respectively. Because of these fluctuations, it is necessary to establish maximum and minimum limits for each commodity or item in stock if effective control is to be exercised.

The maximum limit for any commodity is usually defined as the amount which is not to be exceeded without special permission of responsible executives. The minimum limit, on the other hand, is the amount to which the stock of any item can be depleted before an order is placed for a new supply. The quantity to be ordered is usually designated as the "standard order." The principles which should govern in establishing these three standards have been stated by J. O. McKinsey as follows:

1. There should be at all times sufficient stock on hand to satisfy customers' demands, if such demands are consistent with the capacity of the factory.

2. There should not be larger stocks on hand than can be turned over in a period necessary for the production of a similar quantity, unless such quantities do not constitute an economical run.

3. Goods should be produced in quantities large enough to insure economical production.[1]

From the foregoing definitions of these standards it is clear that the "minimum" for any item of finished goods should be equal to the probable sales during the time required to produce a standard order plus a reasonable margin of safety, to insure against contingencies. The "standard order" is determined by the economical quantity to manufacture which has already been discussed,[2] and the "maximum" is the sum of the minimum and the standard order.[3]

These standards are necessary for the control of raw materials as well as finished goods. As will presently be seen, they perform much the same function in both cases but are, of course, determined by somewhat different factors. These differences are accounted for by the fact that raw-material inventories have to do with purchasing and production, whereas finished goods have to do chiefly with production and sales. Instead of the economical quantity to manufacture which determines the standard production order, the economical quantity to purchase must be considered. Instead of the probable requirements of the sales department, the probable requirements of the production de-

[1] *Budgetary Control*, p. 131. [2] See pp. 158–59.

[3] It should be noted that these terms are not always used in the sense indicated above. Sometimes, for example, "minimum" is used to denote "margin of safety," in which case the minimum as defined above is usually designated merely as "the ordering point."

partment must be estimated. The period required for filling a purchase order is substituted for the production period.

Organization for Inventory Control.—The problem of inventory control has so many different aspects that in most organizations it touches the sphere of responsibility of several departments very intimately. In this respect it differs from many activities which are so limited in their scope and implications that sole responsibility for performance can be delegated to a single department. Complete responsibility for foundry, machine-shop, and assembly department operations, for example, can be, and usually is, delegated to a foreman in each of these shop departments. Responsibility for plant transportation sometimes is centralized and delegated to a department organized for the purpose of performing that function. Power production, plant maintenance, employment service, and even production planning are but further illustrations of homogeneous groups of activities for which responsibility can be centralized. The control of inventories, by way of contrast, involves many activities of an essentially different character. Seldom, if ever, is an inventory-control department created and given complete supervision of inventory investments. This method of organization would not only result in combining strikingly dissimilar activities under a single authority but would also bring together activities for which responsibility might better be divided as a means of providing an internal check upon possible misappropriation of valuable materials by careless or dishonest employees.

Analysis of the problem suggests the following classification of functions:

I. Specification:
   a) Determining what to purchase
   b) Determining how much of each commodity to purchase or produce
II. Requisitioning:
   a) Authorizing the purchase of materials and supplies
   b) Authorizing or requesting the production of goods
   c) Authorizing the transfer of materials from stores to the processing departments
   d) Authorizing withdrawals from stores of supplies needed by the various divisions of the organization
III. Purchasing:
   a) Conducting negotiations with vendors
   b) Tracing goods in transit and conducting negotiations with transportation agencies
   c) Receipt, inspection, and acceptance or rejection of inbound shipments

IV. Stores-keeping:
  a) Custody of raw materials and supplies
  b) Custody of finished goods
V. Record-keeping: accounting for—
  a) Raw materials
  b) Goods in process
  c) Finished goods
VI. Anlaysis and verification of inventories:
  a) Taking periodical audits or physical inventories for the purpose of verifying the accuracy of the accounting records
  b) Examining inventories with a view to discovering inactive or non-productive investments

Inventory Specifications.—Inventory specifications involve both quality and quantity considerations. The quality of raw materials often determines the nature of the finished product, and hence may impose serious limitations upon the performance of the production department. Since this department must assume responsibility for the quality of the finished goods, it may reasonably insist upon authority to specify the quality of the raw materials with which it is supplied.

Inventory-quantity specifications include maxima, minima, and standard orders, as already explained. The purpose of these standards is to insure adequate inventories at minimum cost. By purchasing raw materials or processing finished goods in large quantities, certain obvious savings in the cost of placing orders are possible. On the other hand, purchasing or producing more goods than is immediately required results in increased carrying charges due to larger inventories. In setting these standards, it thus is necessary to make a careful analysis of costs in order to determine what constitutes the most economical inventory investment. Neither the purchasing nor the production departments is usually in a position to assume responsibility for such a task which logically falls within the province of the executive in charge of accounting and statistical records.

Inventory Requisitions.—If the control of inventories is to be effective, the purchase and use of materials must never be permitted without proper authorization by a written order or requisition. Where compliance with such an order involves the purchasing of materials or supplies, it is called a "purchase requisition." An order instructing the production department to manufacture certain needed goods is called a "production requisition," while an order issued by the production

department requesting the storekeeper to release materials needed in the shop is called a "materials requisition."

Purchase and production requisitions usually are issued to replenish the supply of some commodity in stores or finished-goods stockrooms. When proper quantity standards have been established for each commodity, the necessity for issuing such requisitions is indicated when the balance on hand, as shown by the perpetual inventory record, has been depleted to the ordering-point. The requisition procedure is thus reduced to a routine operation which may be intrusted to the clerk who keeps the perpetual inventory record, since he is first to be informed when the supply of any article is depleted.

Authority to issue material requisitions is usually delegated to the production-planning department. Where no such department exists, shop foremen are sometimes given authority to order the materials which they require. This plan is open to serious objection, since it not only makes it more difficult to prevent waste and misappropriation of valuable materials in the shop but also burdens the foreman with important responsibilities for planning whereas it is generally conceded that his function should be confined to supervising performance. In practice a distinction is often made between requisitions for direct materials which are assigned to specific production orders and requisitions for indirect materials and factory supplies. Foremen are inclined to insist that they should be allowed to requisition their own supplies and are thus often given that privilege. They do not, however, always feel obligated to exercise economy in using supplies where their own departments are concerned. For this reason it is well to require supply requisitions to be approved by some central authority. If departmental expenditures are controlled by budget, such a provision merely means that the executive possessing the power of approval is held responsible for seeing that the expense appropriations of each department are not exceeded. This should be a responsibility of the production manager.

Purchasing.—In nearly all modern factory organizations responsibility for purchasing raw materials and supplies is centralized in a purchasing department. These activities ordinarily include:

1. All negotiations with vendors for the purchase of definite quantities of materials of prescribed quality.
2. The tracing of goods in transit.

3. Adjustment of claims in case the materials received do not conform with specifications.
4. Approval of vendor's invoices.[1]

Obviously, none of these activities need directly concern the production department.

The receipt and inspection of inbound shipments, however, may rightly be regarded as functions of the production department. The performance of this department depends in large measure upon the suitability of the raw materials and supplies with which it is provided. To function effectively, it must be given the right both to specify what shall be purchased and to pass judgment upon what is actually delivered. Inspection of inbound materials is necessary for three reasons:

1. To provide assurance that the materials conform with the specifications of the production department.[2]
2. To verify the quantities indicated by the vendor's invoice.
3. To determine the condition of materials when received and to appraise damages if any have been incurred in shipment.

Facilities for performing this threefold task of inspection are of great importance, for failure of a shipment of goods to meet the standards of the organization must be detected when the shipment is received. Otherwise, it is likely that the deficiency will not be discovered until the materials are issued to the shops. By that time important storage and handling costs will have been incurred, the invoice may have been paid, responsibility for the failure will be hard to trace, and the strategic position of those who must seek adjustment of the claim will be seriously weakened. This is especially true when failure to meet specifications is caused by damage in transit, for which a claim should be lodged against the offending carrier. The traffic department, which ordinarily undertakes to adjust such claims, frequently must call in the carrier's representative for joint inspection of the goods immediately after they are received, if its contention is to be successfully maintained. Inspections of the type just mentioned have as their primary purpose the appraisal of damages, and it must be clearly proved that the damage occurred before the goods were received. They are not to be confused with the inspections which must necessarily be performed for every shipment for the purpose of verifying invoices and determining

[1] In some organizations the tracing of goods in transit and adjustment of claims for damage incurred in transit are responsibilities of the traffic department.

[2] This is an essential aspect of quality control, already discussed in chap. ix.

whether the goods conform with the production department's specifications. The verification of invoices obviously is an accounting task but is also of some concern to the production department, since the stores division is held responsible for proper use of the quantities actually vouched for by the receiving department. Responsibility for verifying both quantities and quality may therefore properly be delegated to the inspection division of the production department.

Inspection operations are facilitated by providing a central receiving department where all inbound shipments are delivered and unloaded. In small plants this plan has the advantage that the central receiving-point can be placed at the most accessible location, while the storerooms can be placed so as to insure economical delivery of materials to the shop departments where they are used, the incoming goods being moved by internal transport to the place of storage after inspection. On the other hand, this method is likely to increase handling costs, since the movement of materials to distant storerooms after the original package has been broken for inspection may prove troublesome. To avoid excessive handling costs, large plants usually have a number of storerooms located at the most convenient points, to which inbound goods are delivered directly by the carrier. Receiving and inspection facilities must in such cases be provided at each place of storage. Decentralization is not likely to be objectionalbe under the circumstances, for much of the work of inspection can be performed by the storeroom personnel under the supervision of the inspection department.

Storeroom Control.—The responsibilities of a storekeeper are in some respects similar to those of a cashier. Each is charged with custody of assets which by nature are peculiarly liable to misappropriation and which must in consequence be carefully guarded. Accountability can in neither instance be enforced unless the custodian has complete responsibility for the property intrusted to his care. Moreover, adequate assurance of the integrity of the responsible department must in both cases depend to a considerable degree upon the existence of a satisfactory system of internal checks.[1] To meet these fundamental requirements, it is necessary:

[1] As accountants use this term, a system of internal checks "consists in the accounting records, methods, and details generally of an establishment being laid out so that no part of the account or procedure is under the absolute and independent control of any one person; that, on the contrary, the work of one employee is complementary to that of another; and that a continuous audit is made of the details of the business." (R. H. Montgomery, *Auditing Theory and Practice*, I, 62.)

1. To assign definite responsibility for the custody of the property in question;
2. To exclude all other members of the organization from access to these assets;
3. To provide adequate facilities for safeguarding and economically caring for materials in storage; and
4. To separate responsibility for accounting from responsibility for custody.

Responsibility for store-keeping: In manufacturing organizations the production department is usually responsible for the custody of inventories. The problems of storehouse operation are similar regardless of the nature of the materials to be stored, and there is no valid reason why the same stores organization may not care for all inventories including raw materials, partially processed goods which have been temporarily transferred to storage, and finished merchandise. Raw materials are used only by the production department. Finished and partially processed goods are received only from this department. Storage space must, for the sake of convenience, be located in close proximity to shop departments, and frequently internal transportation equipment over which the production manager has control is drawn into service in moving materials to and from the shop and in the storeroom itself. Stores transactions thus are so intimately related to production operations that it is entirely logical for the storekeeper to report directly to the production manager, just as the cashier ordinarily is a subordinate of the treasurer or financial manager.

Storeroom location: The cost of storing inventories depends in large measure upon the location and the suitability of the facilities with which the stores department is provided. The location of these facilities is but one aspect of plant layout which was discussed in a previous chapter.[1] In most plants the desire to effect economies in the movement of materials has led to an arrangement of shop departments which permits a continuous forward movement of materials through the plant. This plan tends to conserve space, economize internal transport, and facilitate planning and routing of production orders. The storerooms in which incoming materials and supplies are received and the stockrooms to which completed goods are transferred from processing departments must accordingly be located in proper relation to shop processes.

[1] See chap. iv.

Their location is also influenced by the fact that all materials cannot be stored in the same manner. Some goods may be adequately cared for in an open yard. Others require special protection from the elements. Some require careful regulation of temperatures. Others need special protection against theft. Heavy articles must be stored on the ground floor, whereas small articles must be placed in bins. Such variable conditions would present a very difficult problem if it were not for the fact that unified stores control does not necessarily mean centralized storage facilities.

Despite diverse characteristics, however, it is often true that most goods can be stored under the same general conditions. As a rule, the larger the storeroom the more effective can be the internal organization; and unless there is some real reason for decentralizing storage facilities, the multiplication of storerooms should be avoided.

Internal arrangement and fixtures of the storeroom: Within the storeroom the allotment of space for the various types of materials should be carefully planned. Extravagant use of valuable space necessarily results in excessive fixed charges; but on the other hand, crowded conditions may easily give rise to inefficiencies of operation which in the aggregate greatly increase storage costs. It is necessary to provide for more than mere storage of goods. Space must be allotted for receiving inbound materials, for assembling production orders, for aisles and passageways. Where racks or bins are used they should be arranged so as to secure the best possible utilization of natural light afforded by window areas.

Materials which are subject to deterioration should be withdrawn from storage in the same order in which they were received. This is assured by the use of what is commonly known as the "two-bin system." Two compartments are provided for each commodity, and withdrawals are made from compartment A continuously until its contents are exhausted. In the meantime, all incoming shipments are placed in compartment B. The procedure is then reversed, thus insuring that no old stock is left in the bottom of the bin, as is likely to happen if only one bin is used.

An adaptation of this system, which is very useful when materials are controlled by the maxima and minima method, is to place an amount equal to the minimum in a separate bin or section of the main bin. As long as the balance on hand exceeds the minimum, this reserve

stock remains untouched. When it must be drawn upon, it automatically serves notice that a new order must be placed. By holding storeroom employees responsible for reporting all such instances, a useful check is provided upon the work of the inventory record clerk, who ordinarily is responsible for initiating requisitions for reorders.

Indexing and symbolization: It is necessary, when a large storeroom layout is being planned, to devise some comprehensive method for locating stores. Two systems are in common use. In the first, commodities are arranged in the storeroom in alphabetical order so that one who is familiar with the arrangement may quickly locate materials without reference to an index. In the second, storeroom space is designated by appropriate symbols which are assigned to materials in arbitrary fashion. No attempt is made to secure an alphabetical arrangement, but rather to place commodities where they may be reached with maximum convenience. Those which are called for most frequently are naturally placed nearest the point of issue, while inactive stores are placed in less accessible parts of the storeroom. In large storerooms the second method is preferable even though it necessitates maintaining a "finding-list" of some sort. A card record of commodities, arranged in alphabetical order with corresponding symbols, is kept in the storeroom office; and the proper designation is in each instance noted upon the requisition before it is given to material-handlers for filling. This method reduces the work of assembling orders to a routine which makes slight demands upon the memory and intelligence of the storeroom personnel.

Inventory Records.—The function of the stores department is the custody of inventories; and, as in all departments where physical operations predominate, clerical duties and routine record-keeping should be reduced to a minimum. For their own protection stores clerks should keep complete files of all material requisitions and reports of goods accepted and placed in stock. Such records form the written evidence of the operations for which the storekeeper has assumed responsibility. These may seldom be referred to after a given transaction is completed, it is true; but if a question should arise concerning an issue or receipt, the evidence is of considerable importance. The filing device need not be elaborate or costly. Every need is satisfied by filing the storeroom copies of all orders in numerical order in a simple binder.

The most important type of materials record is the so-called "per-

petual inventory," sometimes known as "balance of stores" or "stores and stock ledgers." A common form of this record, which is equally applicable for raw materials and finished goods, is illustrated by Figure 11. A separate card is provided for each commodity; and entries are made in the appropriate columns to indicate the placing of orders, the receipt of goods by the storeroom, and the issue of goods to the using departments. The "Available" and "Applied" columns afford information which is of use to the production-planning department, which

BALANCE OF STORES

Item, ________ Spec. File No. ________ Location
Maximum, ________ Minimum, ________
Ordering Point, ________ Std. Order, ________ Unit, ________

Date	Ordered	Received Dr.			Issued Cr.			Balance		Applied		Available	Remarks
	Units	Units	Price	Amt.	Units	Price	Amt.	Units	Amt.	Units	Prod. Order		

FIG. 11.—Diagram showing the form of stores ledger typically used in a manufacturing plant. Reprinted by permission from W. N. Mitchell, *Purchasing*, p. 352 (Ronald Press).

is often made responsible for maintaining this record. As soon as a production order is placed upon the books, the balance-of-stores clerk is notified as to the probable amount of materials required. This he enters in the "Applied" column, and calculates and enters the proper balance in the "Available" column. The latter is computed by adding the balance on hand to the amount on order and subtracting from this total the amounts applied on production orders not yet withdrawn from stock.

Often such records are designed to show the information in terms of physical quantities only. This is, in fact, all that need be shown in order to determine when reorders should be placed. When the balance

column falls to the ordering-point, the record clerk prepares a requisition for the standard order. When this order has been placed, he is notified and enters the corresponding amount in the "Ordered" column. The "Received" and "Issued" columns are the debit and credit columns of the ledger and are posted for receipts and issues, respectively. The "Balance" is the difference between the totals of these two columns.

For accounting purposes, values as well as physical quantities must be recorded, and hence space is often provided in the "Received" and "Issued" columns for showing both types of information.

Responsibility for Inventory Record-keeping.—As already suggested, there are good reasons for providing for separate responsibility for stores accounting and store-keeping. If one person were responsible for both goods and records, it would be easy for him to withdraw materials without proper authorization and cover the irregularity by a false entry in the record. It is not impossible, of course, to discover fraud of this sort, but it may require a thorough audit to do so. It may be argued that in a large stores department adequate checks may be maintained within the department itself; that the record clerk has no more access to the actual materials than the materials-handler has to the records. This is in a measure true; but the efficiency of the check depends upon prevention of collusion, and there is much more likelihood of collusion between two employees in the same department than in separate departments.

It should be noted that perpetual inventory records in the modern organization comprise an important unit in the accounting record system. They are not merely memoranda which are of service to the production department, but are in reality subsidiary ledgers showing, in detail, information concerning inventory values which is summarized in appropriate general-ledger accounts in the accounting department.[1] This relation to the general-ledger accounts is shown by Figure 12, illustrating the inventory record system of a manufacturing concern which produces several types of assembled machine products from standard parts manufactured for stock in its own shops on a job-

[1] In this respect they are analogous to an Accounts Receivable or Customer's ledger. Ordinarily, a Control account called "Accounts Receivable" is carried in the general ledger. This control is supported by the Customer's ledger, which contains a separate account with each customer. The total of all customers' balances will, of course, equal the balance shown in the general-ledger control account if the books are in balance.

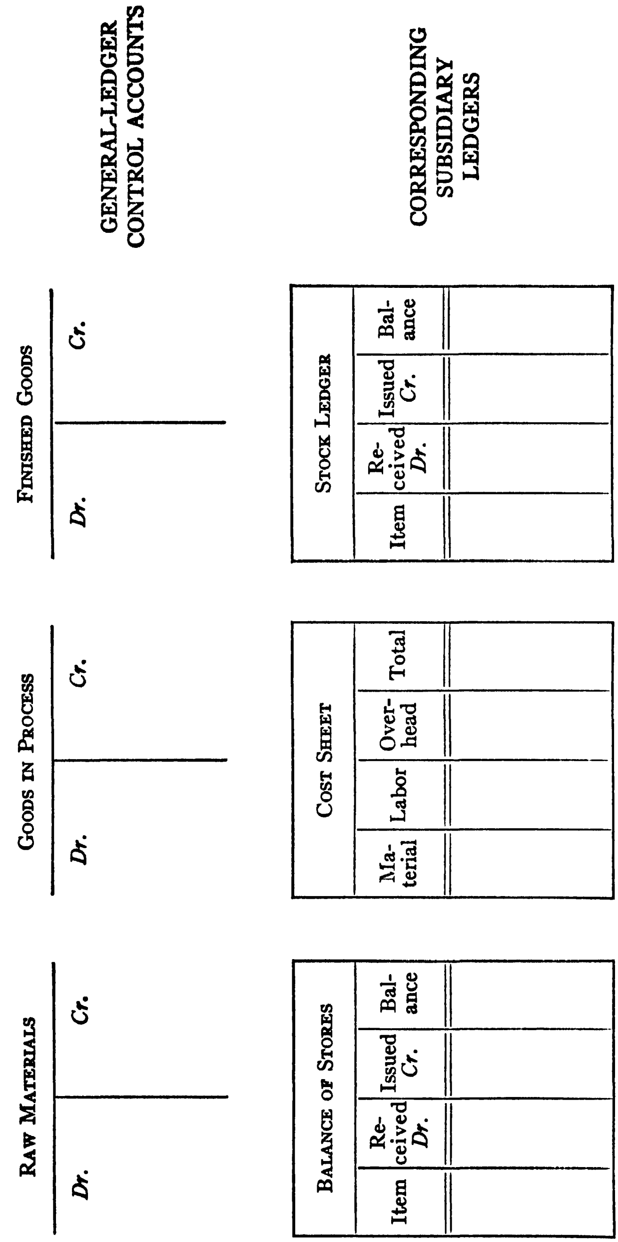


FIG. 12.—Chart illustrating the relation between the general-ledger accounting controls and the corresponding subsidiary inventory records.

order or intermittent basis. Each sheet in the subsidiary ledgers carries a record or account with some specific commodity or job order, and the totals for all sheets in each ledger should be in agreement with the balance in the corresponding control account. When no such agreement exists, it is conclusive evidence that errors have been made. The "tie-in" thus provided constitutes a check on the accuracy of the inventory records which would be lacking were these records to be maintained merely as memoranda with no relation to the general-ledger accounts.

Since the stores and stock ledgers thus constitute a part of the records of the accounting department, it might be argued that they should be kept in this department. In practice, however, this is not always feasible. As already noted, these records supply some information which is of service to the production-planning department only. A very close contact must exist between the inventory record clerk and those who are responsible for planning and initiating operations in the shop. The close relation between this record and those of the accounting department may be recognized, however, by the delegation of responsibility to the chief accountant for general supervision of the record-keeping function.

Analysis and Verification of Inventories.—A very important requisite for effective inventory control is the provision of means whereby inventory records are systematically verified and the physical inventories themselves are subjected to a critical examination with a view to determining whether the values reflected by the books are justified. Where no perpetual inventory record is maintained, an actual count of materials in the storeroom is necessary before the profits of a given period can be determined. With such a record profits may be determined without an actual count of materials on hand, and the physical inventory becomes merely a means of checking the accuracy of the ledger balances.

Where goods must be counted each time it is desired to determine the operating profits or losses, obviously the count must be accomplished within a short period or the value of the results will be destroyed by changed conditions before the stock-taking is completed. Thus, before the practice of keeping a perpetual inventory record was generally adopted by manufacturing organizations, it was customary to set aside

a given time at certain periods of the year for stock-taking, often at the cost of serious interruption of the normal processes of the plant. On the other hand, where stock-taking is primarily an audit, the checking may go on continuously. A permanent "inventory squad" may be organized which checks stores in a given order, covering the entire storeroom possibly once each month or quarter.

The continuous inventory has obvious advantages. It can be arranged so as to cause a minimum of disturbance in the ordinary routine. The crew which is constantly employed at the same kind of work becomes more expert than if it were to be recruited from workmen ordinarily employed at other tasks. It gives greater flexibility in that the audit may be arranged so as to be taken more frequently in some sections of the storeroom than in others where less active stocks are kept, and the work of adjusting the ledgers is spread throughout the year rather than concentrated in a single short period.

It is open to the objection that at no time are the absolute quantities of goods on hand known, and these should be the basis of the valuation appearing in the financial statements for the enterprise. But if care is exercised both in keeping the stock ledgers and in making the audit, it is likely that the quantities shown by the books at any time will be as accurate as are those ordinarily obtained by a physical inventory taken under the usual hurried conditions. An impartial auditor would probably be justified in accepting the results as readily in one case as in the other.

An important by-product of the physical inventory is the opportunity it affords to make an analysis of inventory values. Such an analysis must supply information as to the rate of turnover of inventories and indicate losses caused by spoilage and obsolescence. In detecting obsolete inventories, a comparison of the stock ledgers and the physical inventory often is useful. The absence of entries in a stock-ledger account for a considerable length of time indicates a condition which should be investigated. Inactive inventories should, in many instances, be scrapped; and unless an examination is made systematically at stated intervals, obsolete goods are likely to accumulate in the storeroom.

Illustrations of Inventory-Control Procedures.—The interrelation of the various activities associated with inventory quantity control in a manufacturing enterprise which have been discussed in this chapter

may best be illustrated by concrete procedures designed for use in a specific situation. Such procedures are described in the remaining pages of this chapter.

DESCRIPTION OF THE INVENTORY-CONTROL PROCEDURES OF A MANUFACTURING ENTERPRISE

The following procedures have been adapted from the organization and instruction manual of a manufacturing company. In order that they may be better understood, the following facts with respect to the organization and methods of the company are mentioned:

1. Reporting to the general manager are the sales manager, purchasing manager, traffic manager, treasurer, controller, and production manager.

2. The company is engaged in the manufacture of electrical machinery of a number of standard types and sizes. All types are assembled from standard parts most of which are manufactured in the company's own shops, the remainder being purchased from outside parties in finished form. In all cases these parts are provided in anticipation of the needs of the assembly department and are in the meantime held in stock in the store department. Assembly operations are performed only as required from day to day to fill current sales orders.

3. Specifications for all materials and supplies employed in production are prepared by the engineering division of the production department.

4. Standard inventory quantities for all raw materials, supplies, and finished parts are determined by an assistant to the controller, who in this capacity works in co-operation with the production department forces. The standards in all cases must be approved by the production manager before being adopted.

5. A central store department is responsible for the custody of all raw materials, supplies, and finished parts. The general storekeeper is responsible to the production manager.

6. Perpetual inventory records, called "stores ledgers" in the case of raw materials and supplies, and "stock ledgers" in the case of finished parts, are maintained by a balance-of-stores clerk and a stock-ledger clerk, respectively, who are responsible to the production engineer, who is the responsible head of the production-planning department. These records are in each case regarded as subsidiary ledgers which are controlled by appropriate accounts in the general ledger of the accounting department, and the bookkeeping procedure is supervised by the chief accountant, who reports to the controller.

7. The production-planning department proper, which is under the production engineer, is composed of three divisions under a route clerk, a scheduling clerk, and a dispatch clerk, whose respective functions are those commonly assigned to these divisions where a centralized planning department is provided.

8. A continuous audit of inventories is performed under the direct control and supervision of the controller.

PURCHASING PROCEDURES

1. *Responsibility for the initiation of purchase requisitions:* The balance-of-stores clerk shall be responsible for the initiation of all material and supply requisitions drawn on the purchasing department.

2. *Notice of minimum:* In the storeroom all materials and supplies shall be stored in such a manner that the storeroom worker cannot fail to note, in the course of drawing materials, when the allowable minimum of that specific material is reached; and he shall be responsible for bringing such notice to the attention of his foreman or properly authorized person by placing upon such bin or rack containing the depleted material a "notice of minimum" in a conspicuous place provided for the purpose. (The "notice of minimum" is a simple red tag specially provided with space for inserting the appropriate symbol representing the store in question.)

At stated intervals the storeroom clerk assigned to such work shall pass through the storeroom and collect all such notices, classify them in the most convenient manner, and send them to the balance-of-stores clerk for his information and check against his perpetual inventory record.

The notice of minimum from the stores department is not provided as an authorization to the balance-of-stores clerk to issue a requisition for purchase, since he already has such notice from his own record. Its purpose is to provide a double check at this important point, thus insuring that the reordering of materials shall not be overlooked.

3. *The purchase requisition:* When a minimum for any material has been reached, as reflected by the perpetual inventory record, the balance-of-stores clerk shall issue a purchase requisition in quadruplicate.

The original shall be sent to the purchasing department as the authority for placing the order. The second copy shall be sent to the general accounting department for its information. The third copy shall be sent to the stores department in acknowledgment of the notice of minimum. And the fourth copy shall be retained for file by the issuing department.

4. *Disposition of the purchase requisition:* The original of the requisition, when received in the purchasing department, shall be passed to the purchase-requisition clerk, who shall verify the quantity requisitioned to insure its agreement with the standard ordering quantity as shown by the record kept in this office.

He shall also, upon the basis of the information contained in the vendor files, prepare a memorandum on standard form No.______ to accompany the requisition, noting the names of accredited vendors offering this goods, the date of the last purchase and the vendor from whom purchased, price paid, etc., together with reference to the standard specifications covering the goods to be ordered.

5. *Placing the order:* The file thus prepared by the purchase-requisition clerk shall be passed to the buying section, which is responsible for conducting purchase negotiations.

The purchase shall be made in the manner most convenient under the circumstances at the discretion of the buyer, who, when the transaction has been consummated, shall note on the requisition, in the space provided for the purpose, the name of the vendor, price paid, and other information necessary for the preparing of the written order.

All purchase transactions thus entered into are subject to the review of, and must be approved by, the head buyer.

6. *The purchase order:* The purchase requisition and accompanying memoranda designating the terms of the transaction, when duly approved, shall be passed to the order clerk, who shall be responsible for issuing the written order. Six copies of the purchase order shall be made upon standard order form No.______.

The original shall be sent to the vendor as written corroboration of the order. The second, third, and fourth copies are for the information of the accounting, traffic, and receiving departments respectively. The fifth copy shall be sent to the balance-of-stores clerk as acknowledgment of the requisition issued by him, and serves as the authorization for posting to the "Ordered" column in the stores ledger.

The sixth, or file, copy supplies the basis for entering the order in the purchase-order register in the order of the serial order numbers, and shall be placed in a tickler file for the information of the order-tracing clerk.

The original of the purchase requisition shall then be stamped with the number of the purchase order covering, and shall be filed in the order of the serial requisition numbers for reference in case of need.

7. *Tracing the order:* The order-tracing clerk shall be responsible for tracing all outstanding orders prior to shipment by the vendor, keeping a record of vendors' acknowledgments and of probable dates of shipment. He shall notify the traffic department concerning shipping dates and shall supply the latter with all information needed for tracing the order while in transit.

8. *Tracing the shipment during transit:* The traffic department shall be responsible for tracing all orders after shipment. It shall be kept informed concerning outstanding orders and shipping dates as noted above (see secs. 6 and 7) and shall follow the order until relieved of further responsibility by the report of the receiving department.

9. *Receipt and acceptance of shipments:* The receiving department shall be responsible for receiving, unpacking, inspection, and acceptance or rejection of inbound goods.

It shall be informed concerning outstanding orders by a copy of the purchase order (see sec. 6) and, upon receipt of the goods, shall inspect same to insure their agreement with house specifications, and prepare a receiving report, standard form No. ______, noting thereon the kind and quantities of goods received, with necessary identifying marks, the condition of the shipment, together with notice of acceptance or rejection.

Five copies of the receiving report are required. Copies one to four inclusively will be sent to the purchasing department, the traffic department, the balance-of-stores clerk, and the general accounting department, respectively, for their information.

10. *Disposition of inbound materials:* If incoming goods have been accepted, the receiving department shall turn them over to the stores department without delay, and the latter shall issue a receipt for them on standard form No. ______.

The storage report shall be made in triplicate, copies one and two being sent to

the balance-of-stores clerk and the general accounting department, respectively, for their information and record. For the balance-of-stores clerk this report will be the authorization for posting to the "Received" column in the stores ledger, thus closing the transaction in so far as the inventory record is concerned.

11. *Disposition of damaged or rejected goods:* The receiving department is responsible for determining whether the goods received agree with the standard specifications and is granted authority for acceptance or rejection accordingly. Rejection may be for two causes: (1) damage in transit and (2) unsuitability of the goods when shipped.

It shall be the duty of the receiving department to determine the responsibility for the unsatisfactory condition of rejected goods and to note same when making its report (see sec. 9), and the receiving department shall in that case hold the goods subject to instructions from the purchasing department in regard to their disposal.

12. *Goods damaged in transit:* In case of rejection because of damage in transit, it shall be the duty of the traffic department to negotiate an adjustment with the offending carrier and issue instructions to the purchasing and receiving departments as to the disposition to be made of the goods.

13. *Goods rejected because of failure to meet specifications:* In case of rejection of goods because of their failure to meet specifications, it shall be the responsibility of the purchasing department to negotiate an adjustment with the vendor; and this department shall be further responsible for issuing instructions to the receiving department covering the disposition of same.

14. *Returned shipments:* In case of instructions by the purchasing department entailing the return of the goods to the vendor, the receiving department shall be responsible for repacking the goods in a manner which shall insure satisfactory shipment and returning same.

The receiving department shall in that case prepare a returned-goods report, standard form No. ______, in triplicate. The original copy shall be sent to the purchasing department in acknowledgment of the instructions issued, and the second copy shall be sent to the general accounting department for its information when passing the invoice.

15. *Payment for goods received:* All substantiated claims for goods received and accepted shall be paid promptly in order to secure the benefits of discounts for cash. Payment shall be made only upon the presentation of invoice which has been duly verified and approved. It shall be the duty of the invoice clerk in the purchasing department to trace vendors for prompt presentation of bills.

16. *Disposition of the invoice:* The invoice, when received from the vendor, shall be checked against the purchase order and the report of the receiving department. The extensions shall be verified and it shall be "dressed" in triplicate on standard form No. ______. The first copy shall be pasted to the invoice, the purchasing department's approval shall be noted thereon, and it shall be sent to the general accounting department as the evidence for crediting the vendor upon the books and initiating payment. The second copy shall be sent to the balance-of-stores clerk, to whom it supplies the information required concerning the cost of the goods. (The balance-of-stores clerk keeps a record of the costs of all incoming goods and is

responsible for pricing all requisitions for materials and supplies in the production departments.)

17. *Preparation of the voucher and making payment:* The responsibility of the purchasing department for securing payment shall cease with the sending of the approved invoice to the general accounting department.

In the latter department the invoice shall be passed to the vouchers-payable section, where it shall be checked for accuracy against the purchase order and the "received" report. If found correct, a voucher shall be prepared authorizing payment and making proper distribution in the voucher register. On the date when payment falls due, a check shall be drawn to the order of the vendor and supported by a copy of the voucher shall be sent by the vouchers-payable section of the accounting department to the treasurer, whose signature and release of the check completes the transaction.

18. *Adjustment of claims upon creditors:* All invoices covering claims of creditors for goods purchased, but which have been rejected in whole or in part by the receiving department and for which adjustment is pending, must be approved by the purchasing manager in person before they may be released to the accounting department for payment.

In cases of partial rejection of goods from known and reputable vendors with whom continuous business relations are maintained, it shall be within the authority of the purchasing manager to release invoices as presented, for the full amount, pending adjustment by the vendor's memorandum bill, in order to insure prompt payment. In no case, however, shall bills in question be released for payment without his signature.

19. *Adjusting memoranda:* The purchasing department shall have sole authority concerning negotiations for adjustment of claims upon vendors, who, in case the claim is allowed, will issue to the purchasing department their memorandum bill covering the amount of the adjustment.

The adjustment clerk shall be responsible for the verification of all such bills and, if correct, shall rewrite the memorandum bill in triplicate for distribution to the departments interested.

If the invoice has not been released, such adjusting memo bills shall be attached to the copies of the invoice, thus supplying authorization for payment of the proper amount due.

If the invoice has already been released, such memoranda shall be sent through the regular channels to the general accounting department and the balance-of-stores clerk as authority for making proper adjustments in the accounts.

FINISHED-PARTS PRODUCTION PROCEDURES

1. *Production requisitions:* Requisitions for the production of finished parts shall in all cases be originated by the stock-ledger clerk in the same manner as are purchase requisitions by the balance-of-stores clerk, as already described. When the supply of any item is depleted below the ordering-point, the storekeeper shall send a notice of minimum to the stock-ledger clerk, and the latter shall issue a production

requisition in triplicate on standard form No. ______ for the standard ordering quantity for the commodity in question.

The original shall be sent to the production engineer (responsible head of the production-planning department) for his approval and disposition. The second copy shall be sent to the stores department as acknowledgment of its notice of minimum. The third, or file, copy shall be retained by the stock-ledger clerk and provides the basis for an entry for the proper quantity in the "Ordered" column of the stock ledger.

2. *Disposition of the production requisition:* When approved by the production engineer, the production requisition shall be passed to the route clerk in the production-planning department, who shall prepare (among other documents contained in the route file) material requisitions in triplicate. These shall be detached from the route file for the order in question and shall be sent to the balance-of-stores clerk, to whom they serve as notification that materials as noted will presently be required by the production departments.

If sufficient materials are on hand, the balance-of-stores clerk shall initial the requisitions and enter the quantities called for in the "Applied" column of the stores ledger.

The requisitions shall then be returned to the scheduling clerk in the production-planning department, who shall reattach them to the route file of the production order in question.

If sufficient materials are not in stock, the balance-of-stores clerk shall enter the quantities required in the "Applied" column as before, and shall immediately issue a purchase requisition for the desired quantity as previously described. He shall also determine the probable date of delivery and notify the scheduling clerk immediately when the materials will be available.

3. *Withdrawal of materials from stores:* The scheduling clerk is responsible for scheduling all production orders, after which the route file is passed to the dispatch clerk, who is responsible for issuing all instructions required in initiating a production order. At the proper time the first and second copies of the material requisitions shall be sent to the storekeeper, to whom they represent authorization for releasing the materials requested to the shop departments. When they have been issued, this fact is noted by the stores department upon the original copy of the requisition, which is then returned to the dispatch clerk, who is thereby notified that his instructions have been carried out. The second copy of the requisition is retained in the file of the stores department.

4. *Recording material issues:* The dispatch clerk shall in turn send the original copy of the requisition to the balance-of-stores clerk, who shall record the quantity withdrawn in the "Issued" column of the stores ledger. He shall also compute the cost of the materials and enter same on the requisition, which he shall then send to the cost department, to which it supplies the evidence from which materials costs are posted to proper accounts in the cost ledgers.

5. *Disposition of finished parts when completed:* Shop foremen shall, upon completion of a production order, notify the dispatch clerk and shall deliver the finished goods to the stores department. The latter shall immediately notify the stock-ledger

clerk by standard form No. ______ that finished parts of the specified kinds and quantities have been received and placed in storage.

The dispatch clerk shall in turn notify the cost department that the order has been completed, with instructions to close out the job order. When the latter department has done this and computed the unit cost of the goods in question, it shall report this information on standard form No. ______ to the stock-ledger clerk, who shall accordingly make appropriate entries in the "Received" column of the stock ledger, thereby closing the transaction.

PRODUCT-ASSEMBLY PROCEDURES

1. *Originating assembly orders:* Assembly operations shall be undertaken only as required to fill sales orders, and shall be based upon a summary of sales orders prepared and transmitted by the sales manager each day to the production department.

2. *Disposition of production requisitions:* This summary, when received by the production-planning department, shall be its authority for initiating assembly operations; and it shall accordingly prepare finished-parts requisitions in triplicate for the necessary materials. At the appropriate time the first and second copies shall be sent to the stores department, to which they supply authority to release the desired materials for the use of the assembly department. When issued, the storekeeper shall indicate same by initialing the original, and shall then return this copy to the dispatch clerk in the production-planning department. The latter shall in turn transmit this copy to the stock-ledger clerk, who is thereby authorized to make appropriate entries in the "Issued" column of the stock ledger. He shall then note the cost of the materials in question upon the requisition and send it to the cost department, to which it supplies the required evidence for making appropriate postings in the cost accounts of the assembly department.

SUPPLY-CONTROL PROCEDURES

1. *Purchase and storage of supplies and indirect materials:* The purchase, storage, and accounting for supplies and indirect materials used by the factory shall be controlled in the same manner as direct materials, as already specified.

2. *Supply requisitions:* The foreman of each department shall on the first and the fifteenth of each month prepare requisitions in triplicate for all supplies which will be required during the ensuing period in his department, and shall transmit the first and second copies to the production manager.

3. *Disposition of supply requisitions:* In the production manager's office, supply requisitions shall be compared with the budgetary supply appropriations for the department making the request and, if consistent, they shall be approved.

The requisitions of all departments shall then be combined and summarized, and a copy of this summary shall be sent to the balance-of-stores clerk. The original requisitions shall be sent to the stores department as authorization for the delivery of the materials requested to the several departments. When issued, the storekeeper shall indicate this fact by initialing the original copy, which he shall then send to the balance-of-stores clerk. The second copy shall be retained for the stores-department files.

4. *Record of supply issues:* The original copy of the supply requisition, when properly vouched by the stores department, is the authorization to the balance-of-stores clerk for making appropriate entries in the "Issued" column of the stores ledger, after which he shall enter the cost of the supplies withdrawn in space provided for that purpose upon the requisition and shall forward it to the general accounting department, to which it supplies the evidence for appropriate expense charges in the general-ledger accounts.

PLANT OPERATION

CHAPTER XI

STANDARDS OF PERFORMANCE

The Control of Production Operations.—Machines, materials, and men comprise the three factors with which the problems of production management deal. In preceding chapters attention has been directed more particularly toward the issues involved in providing and maintaining the first two of these resources. There yet remains the task of considering these physical elements in their relation to the human resources of the enterprise whereby the plant is transformed into a living organism capable of converting raw materials into finished goods. This latter aspect of the production problem constitutes what may, for the sake of convenience, be called the "control of operations."

In laying the groundwork for successful plant operation several important considerations are presented:

1. Operating standards must be established. No organization can function efficiently without standards by which duties and tasks are specified and performance is in turn measured and evaluated.
2. An organization must be effected. Duties must be assigned. Lines of authority must be established. And all production activities must be co-ordinated in such a manner that the department may act as a single unit.
3. A definite plan or program of operations must be formulated.
4. Procedures designed to facilitate the accomplishment of the desired results must be devised, and means must be provided whereby they may be enforced.
5. A proper system of curbs and incentives must be devised if the enthusiastic co-operation of the working force is to be obtained.
6. Results must be properly recorded and interpreted.

Attention will be directed toward each of these considerations in the remaining chapters of this study.

To some it may seem that, in suggesting this analysis of the problems of production management, the author has been guilty of certain glaring omissions. Many of the production manager's greatest difficulties lie within the sphere of human relations. In no other department is ability to handle men so important. In no other is the task of recruiting

and training an efficient labor force, of creating and maintaining the morale of the rank and file of employees, so great. In deliberately choosing to confine attention to the means by which these human resources are utilized in the shop, it is not intended to minimize the importance of the means by which these same resources are secured and maintained. It is felt, however, that many of these latter considerations lie within the sphere of personnel administration, and that when the production executive is called upon to deal with these problems, as inevitably he, in common with all executives, must, he is acting in the capacity of a manager of personnel rather than in that of a manager of production. For a discussion of many of the problems relating to employee relationships, therefore, the reader is referred to the voluminous literature of personnel administration.

The Nature of Production Standards.—Modern manufacturing is distinctly a repetitive process. With the introduction of mass production and the standardization of products which such methods necessarily imply, many of the tasks which men and machines are called upon to perform have been reduced to a routine which need not be varied in the slightest degree as different units of the product pass from one work place to another in endless succession. Even in the manufacture of unstandardized products, the necessary variations in the product rarely necessitate radically different methods of production. Many of the elemental operations are identical regardless of variations in the final result.

With standardization of products it is but natural that production operations should also be standardized. The advantages of standardized production doubtless were long ago recognized. In all probability the greatest contribution of those who have been associated with the scientific-management movement has been in the scientific determination of production standards. "Standard," in the sense in which these writers use the term, may be defined as, "that which is set up as a form, type, example, or combination of conditions accepted as correct (for the time being); a criterion, established as a result of scientific investigation, and representing the present stage of development of the art."[1] The standards of scientific management may be classified as follows:

[1] As defined by H. K. Hathaway in an article entitled, "Standards," *Bulletin of the Taylor Society*, Vol. V, No. 1 (February, 1920), and reprinted in Vol. XII, Nos. 5 and 6 (October and December, 1927).

1. Job standards.	Equipment..........	Design Maintenance Adjustment
	Materials.	Quantity
	Shop environment....	Atmospheric conditions Lighting Sanitation Orderliness
2. Standards of performance..................		Methods Accomplishment

The scientific-management movement had its genesis in an endeavor to establish "standards of performance" for the purpose of setting piece rates on a just and accurate basis, and it is standards of this type which will chiefly concern us in this chapter. Purely physical and environmental standards cannot be entirely ignored, however, for, as Frederick Taylor repeatedly pointed out, "there can be no standard or uniformity of accomplishment without standardization of all the conditions under which the work is done."[1] This truth is fundamental. Unless the job is first standardized, time and motion studies undertaken for the purpose of establishing standards of performance are not likely to be justified by results.

Management's Responsibility for Method.—As noted above, standards of performance are of two kinds: (1) standards of method and (2) standards of accomplishment.

The first have as their purpose the introduction of uniformity in the performance of given tasks. The absence of such standards necessarily implies the shifting of responsibility for the choice of methods to the individual workman or his immediate foreman. Choice of methods, however, should be a responsibility of management. Furthermore, it is generally conceded that, in assuming this responsibility and in specifying the methods to be employed by the workman in a given situation, management cannot content itself with simply *a method.* Efforts to promote efficient production and successfully meet competition continually tend to bring into sharp relief the necessity of insisting upon the use of *the best possible methods*, which, so writers on scientific management have always contended, can be discovered only by scientific investigation. Nothing has received more emphasis in the writings of

[1] See F. W. Taylor, "A Piece Rate System," *Transactions of the American Society of Mechanical Engineers*, Vol. XVI (1895).

Frederick Taylor and his followers. Gilbreth in his classic studies of the construction trades found that the methods of laying bricks have not materially changed since the days of the Pharaohs, and demonstrated that even in so skilled a trade there could be little hope for improvement as long as the choice of methods was to be left to the workman.[1] His curiosity was aroused; and upon investigation he found that, although there were wide variations in the output of different workers, even the most efficient were made much more productive without increased physical effort by the methods which a skilled observer was able to suggest. Taylor, himself, made one of his first studies of method in connection with the relatively simple task of handling pig iron, with equally astonishing results. Later, when his attention was directed to the metal-cutting trades, he found that the variables in this much more complex task were so numerous that it was too much to expect that a machinist would by any chance arrive at the best method of performing his work by the process of trial and error. Extensive researches were undertaken, with results with which every student of scientific management is familiar and which laid the foundation of modern shop practice in the metal-cutting trades.[2] The conclusions of these pioneers in the study of method have repeatedly been corroborated by capable analysts who have clearly demonstrated that it is futile to expect a workman to select intuitively the best method of performing a complicated task. The blame for faulty methods under such circumstances must be shouldered not by the workman but by management. The man in the shop labors under the continual stress of maintaining output and has neither the time, the training, nor the facilities for assuming this responsibility of management.

Relation of Method and Accomplishment.—Standards of accomplishment have as their purpose the specification of standard times allotted for performing a given task according to a definitely specified method. It naturally follows that standards of method and of accomplishment are very closely related. The time required for completing a given task depends upon the method employed in performing it. Until methods have been standardized, standard times are meaningless simply because

[1] F. B. Gilbreth, *Motion Study* (Macmillan, 1919).

[2] These researches were first described and made public in Taylor's presidential address entitled, "On the Art of Cutting Metals," which he read before the American Society of Mechanical Engineers in 1906.

there can be no assurance that previous times will be duplicated when the task is next performed unless identical methods are employed.

On the other hand, methods can scarcely be improved unless an investigation is undertaken concerning the time required for accomplishment by different methods. As previously noted, the benefits of method standardization are not fully realized unless the standard adopted represents the best practice under existing conditions. But what constitutes the best method? Other things being equal, the most important criterion is likely to be the time required for completion of the task, since the time consumed in a process is usually a true index of the cost of processing. Because of this interdependence, time study without its concomitant, motion study, seldom is of great value.

Purpose of Standards of Accomplishment.—Time and motion studies which are the means by which standards of accomplishment are established have no doubt often fallen far short of their mark because management, in undertaking such investigations, was inadequately informed as to the use which could be made of the resulting data. As Sanford Thompson has well said,

> Time study is often looked upon simply as a mechanism for setting piece rates, and determination of standard times for fixing incentives is of great value. Time study has, however, a still broader use which is insufficiently recognized. It is a tool for the development and operation of controls that enables management to know what a standard day's work is and to obtain this standard from each machine and work place. Thus a maximum production is secured from a minimum of equipment and personnel. The by-product of this is a highly productive and a *highly paid* personnel.[1]

With no desire to minimize the importance of the contribution of time and motion study work in the scientific determination of piece rates, it may, at the same time, be suggested that this broader conception of the purposes of time standards can scarcely be too much emphasized. The modern philosophy of shop management may be said to be based on securing maximum production with a minimum of effort, that is, at least cost. In striving to attain this ideal, management should not be as much concerned with the amount of wages workmen receive as it is with insuring that the full measure of services thus purchased are rendered and effectively utilized. Whatever other problems the production executive must face, his primary concern is to

[1] S. E. Thompson, "Smoothing the Wrinkles from Management—Time Study the Tool," *Bulletin of the Taylor Society*, Vol. XIII, No. 2 (April, 1928).

secure the greatest return possible from his investment in plant and personnel. His equipment usually represents a large financial outlay which can only be recovered through consistent use. His labor force, likewise, has usually been recruited and trained at great expense and can only be held intact by the promise of regular employment. Regularity of employment and of plant operation, however, cannot be achieved if management is content to deal with emergencies of operation only after they have occurred. Each detail of operations must be foreseen and performed according to schedule. Failure on the part of the planning department is almost certain to result in "traffic jams" in the shop. The flow of work becomes disrupted. Orders pile up at one machine while others stand idle for want of materials. Rush jobs are given special treatment while less urgent work is put aside until it, too, must be rushed, and the workman who but a short while ago may have complained because of lack of work may be forced to work overtime in order to complete the job on time. Such conditions, which cannot fail to undermine the morale of the shop and increase costs, are the inevitable result of faulty planning. But accurate planning is predicated upon ability to determine in advance the time required to perform each operation, and cannot be insured unless adequate time standards are provided. It is in supplying this information, without which the production-planning department finds it difficult to function effectively, that standards of accomplishment often serve their most useful purpose.

A third service performed by time standards is that of enabling the prediction of production costs. The modern tendency is to regard cost information not simply as a matter of history but as an aid in planning and directing operations in the future. Executives cannot afford to wait until the end of an accounting period in order to learn what these operations have cost. What is most needed is information which will enable them to predict future costs. A comprehensive budget program cannot be prepared, the proper proportions of different products which it is proposed to manufacture cannot be determined, nor can the most efficient methods of production be selected, until costs have been estimated. In preparing such estimates some standard of accomplishment is essential.

Importance of Job Standardization.—Standards of accomplishment, because of their great importance in the day-to-day operation of the

shop, tend to eclipse other types of standardization upon which accomplishment in reality depends. The interrelation of method and accomplishment has already been noted. It must also be recognized that both method and accomplishment almost wholly depend upon the job to be performed. Standard times can have no permanent value, nor are they likely to be duplicated in subsequent performance, unless the job to which they relate has also been standardized. The nature of this job is determined by the physical and environmental conditions of the shop, and job standardization, therefore, implies standardization of materials, equipment, and working conditions.

The standardization of materials involves consideration of both quantity and quality. Quantity standards which include those commonly known as "economic quantities to order" and "standard bills of material" are related only indirectly to job performance in that they specify the quantities of materials which should be required to accomplish a given result. While necessary for the prevention of waste and excessive inventories, they obviously have little bearing upon the time required for performance provided the quantities specified are sufficient to supply the needs of production without interruption.

Quality standards have, however, a direct bearing upon the time required to perform a given task. The steaming qualities of coal which is delivered to the boiler-room, for example, as every boiler-room attendant knows, exert a most important influence upon the performance of that department. Gilbreth,[1] in his study of the bricklaying craft, found it worth while to employ a common laborer to cull and arrange the bricks in the most convenient position for the bricklayer so that the latter highly paid workman need not be delayed by lack of uniformity in his materials. One of the chief obstacles encountered in attempting to develop time standards in the woodworking trades is the unstandardized nature of the materials and the uncertainty as to how these will respond to the workman's efforts. In most industries there has been sufficient incentive for standardizing the quality of materials for other reasons, since there can be no uniformity in the quality of the finished product if the raw materials are not first of uniform quality. Those who have been interested in establishing standards of performance have accordingly often found material standards in force even where much lack of uniformity existed with respect to other conditions in the shop.

[1] F. B. Gilbreth, *op. cit.*

Of all job standards, those pertaining to equipment have received most attention. Much of Taylor's research, in which he was ably assisted by Barth, Gantt, and others, was undertaken for the purpose of developing tool and machine standards which he regarded as "an absolutely necessary preliminary to success in assigning daily tasks which are fair and which can be carried out with certainty."[1] Little reflection is needed to convince one that this conclusion is, if anything, even more true now than forty years ago when Taylor's work was first recognized. Often in this age of automatic tools, there is nothing upon which performance depends so much as the machine, not even excepting the operator himself.

Lack of uniformity in the tools and machines which workers employed at similar tasks must use may be caused (1) by failure to purchase only equipment which conforms with the standard design adopted for the shop or (2) by neglect to make repairs and adjustments necessary for maintaining proper standards of efficiency. The first condition is by far the more serious and can be completely remedied only by gradual replacements with equipment of standard design as unstandardized units are worn out. Even in matters of design, however, much may be gained by judicious and inexpensive standardization of minor attachments and auxiliary equipment, such as gears, belts, pulleys, and bolt slots for clamping work on the tables or face plates of machine tools.

Where unstandardized conditions are caused solely by the lack of uniform adjustments, the remedy is more readily found. What is needed under such circumstances is an adequate maintenance policy. This involves:

1. The establishment of adequate maintenance standards.
2. The assignment of responsibility for maintaining these standards. (This should, wherever possible, be delegated to properly instructed and equipped maintenance forces rather than to the worker who uses the equipment.)
3. Effectual inspection at frequent enough intervals to insure that the standards are being maintained.

Recently, much attention has been given to the standardization of what may be called the "environmental characteristics" of the job. The shop environment, including such factors as lighting, ventilation,

[1] F. W. Taylor, "Shop Management," *Transactions of the American Society of Mechanical Engineers*, XXIV (1903), 1402.

sanitation, and orderliness, has an important bearing upon performance by virtue of its effect upon the personnel. Inadequate lighting or ineffectual ventilation tends to hasten fatigue, lower productive efficiency, and, if long continued, may even undermine the health of the workman. Lack of proper attention to factory heating or sanitation is not conducive to shop morale. Careless "housekeeping" and disorder not only hinder the worker but tend to create a frame of mind which is positively injurious to quality and quantity of output.

All such environmental characteristics must be standardized before uniform performance can be expected. This does not mean, of course, that identical standards must be enforced in all departments. The intensive illumination which is necessary for efficient performance of some machine operations or in the proofreading department of a printing plant, where the risks of eyestrain are great, might prove a positive irritant in a forge shop or foundry. The temperatures which best contribute to comfort and efficiency in a department where hard manual labor is necessary are not suitable for departments where bench and office workers are housed. The standards of cleanliness and orderliness which might be considered entirely satisfactory in a foundry would not do at all in the engine-room of the power plant or in the storeroom. The environmental standards of each department must be consistent with its individual needs, and should be established only after the same careful investigation which is necessary for the proper determination of all standards. Like other standards also, they are likely to be of permanent value only when rigid inspections are performed at sufficiently frequent intervals to insure that they are being enforced.

By-products of Job Standardization.—An important outgrowth or by-product of job standardization has been a rather pronounced tendency for management to assume active control of many shop details which formerly were left almost entirely to the workman's discretion. Not many years ago it was common practice for bench and machine workers to provide their own tools. Even when these were supplied by the employer, the workman was ordinarily expected to keep them in repair. When tools were worn out, he took them to the storekeeper and received new ones in exchange which remained in his keeping until they in turn had to be replaced. The care of belting, inspection and oiling of machines, and in some cases even major machine repairs were also commonly left to the worker. If the lighting was poorly adapted for his

work, he was at liberty to rearrange the wiring and fixtures according to his fancy. If he felt the need of more adequate ventilation, he had but to open an adjacent window provided his fellow-workers offered no objection.

Obviously, such slipshod methods cannot be tolerated when the value of standardized conditions is recognized, and management has accordingly been compelled to assume responsibility for these former prerogatives of the worker. Tool departments which provide the worker with properly conditioned tools when a job is to be begun and require that they be returned when the job is completed have come to be regarded as important adjuncts of every well-managed shop.[1] Special maintenance departments which are responsible for keeping machines, belting, and shop fixtures in repair have been provided. Such matters as lighting, ventilation, and temperature regulation, have in many well-managed shops been removed entirely from the jurisdiction of the worker and placed in the hands of shop inspectors who are responsible for enforcing proper standards.

The Worker in Relation to the Job.—Standardization of the means and methods of production will not, however, insure uniformity of accomplishment as long as the workman remains unstandardized. Lack of

[1] That many indirect benefits in the form of mechanical improvements as well as more efficient organization have resulted from job standardization is suggested by the following quotation from H. K. Hathaway, *op. cit.*, p. 492. The italics are by the present writer.

"Having as a result of experiment, arrived at and established as standard, proper combinations of feed, cutting speed and depth of cut, it soon became apparent to Taylor that unless the cutting tools used by machinists were practically identical in quality and temper of steel and ground to practically the same shape, clearance and lip angles, these standards could not be attained. *In this we have the beginning of the long series of experiments and research* described in Taylor's book "On the Art of Cutting Metals" *which culminated in the invention of high speed steel and the Taylor-White process for its treatment; the slide rules started by Mr. Taylor and Mr. Gantt and perfected by Mr. Barth, and the Taylor standard lathe and planer tools.* He found that the time-honored practice of each workman grinding his own tools must be abandoned; and *the development of an automatic tool grinding machine followed*, insuring uniformity and eliminating the loss of production and a variable element in the time taken to do the job as a result of the time spent at the grindstone or waiting his turn to use it.

"Likewise it became evident that not only tools required for cutting, but those required for setting and holding the work in the machines and the tools for measuring, must be standardized and must be of the same kind and in the same good condition as those used when making the elementary studies upon which was based the method and time prescribed —the standard of accomplishment. It was found also that they must be on hand when wanted in order that the workman might not be forced to shift with less suitable or inferior tools. Result: *a tool room from which standard tools were provided.*"

uniformity in inclination, training, or natural skill on the part of the working force introduces an important variable in the performance of any task unless the "pace" or rate of performance is entirely determined by the speed of the machine. Indeed, the entire theory of the piece rate rests upon recognition of this fact. The piece-rate method of wage determination seeks, not only to reward each worker in proportion to his individual output rather than according to the average level for the entire group, but also to provide the incentive required to secure maximum output. By supplying needed incentives, a properly designed rate schedule may conceivably inspire in every worker an equal desire to work; but no piece rate system can of itself secure uniformity of performance if the training and natural aptitudes of workmen are not identical. This fact has always been recognized by the leaders in the scientific-management movement, who have laid great stress upon the importance of selecting and training only those workers who will be capable of performing a standard day's work.

This characteristic of scientific management has, in fact, been severely criticized by many whose sincerity and interest in the worker's welfare cannot be questioned.[1] These profess to see in the insistence upon maintaining a standard day's work no provision for the substandard individual, and they ask, What is to become of the man who, through misfortune or natural inability, cannot conform with the rigid test of efficiency imposed by such a system? This is indeed a serious charge, for as Dean Kimball has wisely remarked, "If these methods are to be used as a means of selecting only the best for industry and of rejecting those who do not rise to a given arbitrary standard, the working classes will have fallen upon evil times."[2]

Fortunately, such fears have often been proved to be groundless. As Taylor himself pointed out, a workman may be incapable of attaining the requisite standard of accomplishment on one task and still give an

[1] These fears are reflected in the cross-examination of Frederick Taylor in connection with the congressional investigation of the Taylor System of Shop Management at the Watertown Arsenal (1913), as reported in Appendix I of the "Report of the Chief of Ordnance." (C. B. Thompson, *Scientific Management*, pp. 754–56.) Upon this occasion Taylor characteristically stated that scientific management had no use "for the bird who could sing but would not." On the other hand, he contended, there is one best job for every man, and it is the duty of management to find that place where the worker can perform a standard day's work.

[2] D. S. Kimball, *Plant Management*, p. 322.

excellent account of himself when put to work on a job for which he is fitted. Because a man is not physically able to do a creditable day's work when handling pig iron is no proof that he may not, with proper training, become an excellent bench worker; and the interests of both employee and employer are best served where management assumes full responsibility for careful placement and training of its working forces. That these beliefs of Taylor were justified has seemingly been corroborated by the experience of some of the most successful of present-day industries.[1]

Responsibility for Production Standards.—Standards of performance are but the culmination of a broad program which, as Taylor insisted many years ago, must include:

> . . . . systematizing of all of the small details in the running of the shop: such as the care of belting, the proper shape of cutting tools, and the dressing, grinding, and issuing same, oiling machines, issuing orders for work, obtaining accurate labor and material returns, and a host of other minor methods and processes. These details which are usually regarded as of comparatively small importance and many of which are left to the individual judgment of the foremen and workmen are shown by the rate fixing department to be of paramount importance in obtaining the maximum output, and to require the most careful and systematic study and attention in order to insure uniformity and a fair and equal chance for each workman.[2]

If this dictum is to be accepted, it may well be contended that one of the most important activities of the production manager must be the insuring (1) that standards covering "all the conditions under which the work is done" shall be established and (2) that facilities shall be provided for maintaining these standard conditions. Co-ordination requires that responsibility for determining all such standards shall be centralized. All are intimately related. Standards of performance cannot long be maintained unless standardization of equipment, of materials, and of working conditions are also maintained. The analyst who is responsible for determining time standards must be given a voice in the determination of methods and the physical conditions which limit performance.

[1] As corroboration of this contention the following statement from a pamphlet entitled *The Ford Industries*, published by that company in 1924, is interesting: "There are probably 5,000 jobs in the Ford factories that do not require full physical capacity, and a surprisingly large number of these may be performed by men for whom steady work was at one time considered physically impossible. . . . . No man is ever discharged from Ford employ merely because he is physically unable to do his work. Instead a new job where he can acquit himself satisfactorily is found."

[2] F. W. Taylor, "A Piece Rate System," *op. cit.*, p. 877.

Failure to recognize the importance of the analyst's work has sometimes brought time-and-motion-study work into ill repute. Too often such studies have been regarded merely as a matter of slide rules and of stop watches. As has been said,

> Lack of appreciation of its importance on the part of chief executives may lead, on the one hand, to hiring of inexperienced young men to handle a job which requires experience and judgment and, on the other, to the engaging of service vendors to introduce a "system" dealing simply with the placing of a piece price upon a job without regard to its manner of performance or to its setting in the business as a whole.[1]

It is well to remember, however, that a more expert handling, a more careful training, and a higher order of intelligence are required for analyzing studies and establishing standards than for taking the studies themselves. The making of actual observations and recording of time data in the shop is likely to appear to the uninitiated to be a simple matter, and does, in fact, require a type of skill that is readily acquired. The chief requisites for such an observer are that he be able to meet the operator on his own level and secure his co-operation; that he possess sufficient knowledge of the operation under observation to plan the study and discern what should be recorded; that he possess the power of accurate observation; and that he be able to prepare a record which is intelligible to persons other than himself. Abilities of this type are not difficult to obtain.

Experience has shown that the real test of results depends upon the analyst who examines the raw data, makes necessary allowances and corrections, and finally arrives at a standard which can be maintained day after day in practice. Such a task is not to be regarded lightly nor begun without careful preparation. It is not to be placed in inexperienced hands nor to be assigned to an already overburdened foreman. It demands the services of a technical expert who is equipped by training and experience both to command sympathetic co-operation and loyalty from workmen and to make constructive suggestions with reference to improvement of the physical factors which condition the work.

Technique of Time and Motion Study.[2]—Most experienced analysts agree upon two essential principles of time study:

[1] S. E. Thompson, *op. cit.*, p. 69.

[2] In the discussion of time and motion study in this chapter it is not proposed to do more than present in brief outline some essential, though often neglected, aspects of the operation. For a comprehensive treatment of the many problems which invariably confront the practitioner the reader is referred to W. O. Lichtner, *Time Study and Job Analysis*, and A. G. Anderson, *Industrial Engineering and Factory Management*, chaps. xx–xxii, inclusive.

1. Observations must be sufficiently accurate and must be repeated often enough to present a typical sample of the operation being studied.
2. Studies must be made of the time elements of each operation, divided into small enough units to be utilized in various combinations.

The first of these is self-evident and needs little comment. Time study consists always of a process of sampling, and it is important that the sample or cross-section chosen be typical of the whole or the results will be valueless. A study which meets these general requirements is illustrated by Figure 13. It will be noted that in this study the stop watch has been run continuously, which is the method most frequently employed by skilled observers. By so doing, all time is in some manner accounted for on the record. The method is less liable to error in recording operations of short duration, and requires a minimum of mental effort upon the part of the observer, thus allowing him to concentrate his attention upon the operation under observation.

Concerning the second principle, a leading authority has written as follows:

> As long ago as 1885, Frederick W. Taylor developed the principle of unit times; that is, the breaking up of an operation into motions or elements which can be used for recombination into various other operations in the same way that the twenty-six letters of the alphabet in different combinations can be made to spell many thousands of words. Notwithstanding the time that has elapsed—over forty years since this discovery by Taylor—it is astounding how few time studies are made in such a way that they can be utilized properly. In other words, the vast majority of so-called time studies, even at the present time, simply record the total time of the single operation observed, with no thought of the best method, with no analysis of delays and with no recording of the elements of which the operation is composed.[1]

The practical application of the principle of unit times will be made clear by a simple illustration.

Three jobs are to be performed as follows:

1. The first consists of drilling a hole $\frac{1}{2}$ inch in diameter through a piece of metal $\frac{3}{4}$ inch thick, as indicated in the study, Figure 13.
2. The second consists of drilling two holes, each $\frac{1}{2}$ inch in diameter to a depth of $\frac{1}{2}$ inch and 1 inch, respectively.
3. The third consists of drilling two holes each to a depth of $\frac{1}{2}$ inch, the first to be $\frac{1}{2}$ inch in diameter and the second $\frac{5}{8}$ inch in diameter.

[1] S. E. Thompson, *op. cit.*, p. 71.

THE WESTERN MANUFACTURING COMPANY

Time-Study Record Sheet

Part sym. *K406* Date *7-9-27*
Observer *J. F.*
Operation *5* Occupation No. *M348*
Dept. *24* Bldg. *M.S.* Floor *1*
Workman No. *279* Helper No.

Classification of—

Workman	Job	Conditions	
√ Fast	Heavy	Standing	Hot
Slow	Med. hvy.	√ Sitting	Cold
Av.	√ Light	Stooping	Wet
√ Consistent	Major	Dangerous	Oily
Spasmodic	Simple		Dusty

Dimen. of work *¾″×4″×12″*
Wgt. per piece *4#*
Pieces in lot *25*
Material *M.S.*
Coolant *√*
Machine No. *D131*
Type of jig *√*

Speed r.p.m. Speed in feet Should be
Feed per min. Per rev. Depth of cut *¾″*
Gauge limits Remarks: *Machine was tested and adjusted prior to beginning observations*

Tools on hand: Should have:
3 extra drill bits
"S" wrench
Spanner

Condition of—
Belt *OK* Light *OK*
Coolant *OK* Sanitation *OK*
Equipment *OK*

Detail elements:	Total	No.	Av.
a *Procure materials*	*4.15*	*1*	
b			
c *Check dimensions*	*0.91*	*1*	
d *Drill*	*23.56*	*25*	*0.94*
e			
f			
g			
h			
i			
j *Set jig*	*2.68*	*1*	
k *Remove jig*	*1 18*	*1*	
l			
m			
n			
o			
p *Place piece*	*7 75*	*25*	*0.31*
q			
r *Remove drill*	*1.71*	*2*	*0.85*
s *Set drill*	*2.10*	*2*	*1.05*
t			
u			
v			
w *Mark order*	*0.88*	*1*	
x *Unnecessary delay*	*1.50*	*1*	
y			
z *Clean machine*	*4.75*	*1*	

Sym.	Read.	Ex.	Note	Sym.	Read.	Ex.	Note
o	*0.00*			*d*	*9.10*	*0.64*	
a	*4.15*	*4 15*		*p*	*.53*	*0.43*	
s	*5.42*	*1.27*		*d*	*30.36*	*0.83*	
j	*8.10*	*2.68*		*p*	*0.72*	*0.36*	
p	*8 45*	*0.35*		*x*	*2.22*	*1.50*	
d	*9.41*	*0.96*		*d*	*3.31*	*1.09*	
c	*10.32*	*0.91*		*p*	*.59*	*0.28*	
p	*0.70*	*0.38*		*d*	*4.51*	*0.92*	
d	*1.64*	*0.94*		*p*	*.86*	*0.35*	
p	*1.91*	*0 27*		*d*	*5.77*	*0.91*	
d	*2.86*	*0.95*		*p*	*6.04*	*0.27*	
p	*3.15*	*0 29*		*d*	*7.11*	*1.07*	
d	*4.06*	*0.91*		*p*	*.42*	*0.31*	
p	*4.37*	*0.31*		*d*	*8.31*	*0.89*	
d	*5.01*	*0.64*		*p*	*.53*	*0.22*	
p	*5.24*	*0.23*		*d*	*9.47*	*0.94*	
d	*6.40*	*1 16*		*p*	*.74*	*0.27*	
p	*.92*	*0.52*		*d*	*40.64*	*0.90*	
d	*8.06*	*1 14*		*p*	*.98*	*0.34*	
p	*.30*	*0 24*		*d*	*2.12*	*1.14*	
d	*9.24*	*0.94*		*p*	*.48*	*0.36*	
p	*10.51*	*0 27*		*d*	*3.51*	*1.03*	
d	*20.46*	*0.95*		*r*	*4.36*	*0.85*	
p	*0 74*	*0.28*		*k*	*5.54*	*1.18*	
d	*1.61*	*0.87*		*w*	*46.92*	*0.88*	
p	*.89*	*0.28*		*z*	*51.17*	*4.57*	
d	*2.93*	*1.04*					
p	*3.27*	*0.34*					
d	*4.35*	*1.08*					
r	*5.21*	*0.86*					
s	*6.04*	*0.83*					
p	*.32*	*0.28*					
d	*7.25*	*0.93*					
p	*.51*	*0.26*					
d	*8.20*	*0.69*					
p	*.46*	*0.26*					

Fig. 13.—Illustrating a form of time-study record sheet. (Note: The data shown are illustrative only and do not represent actual conditions.)

Using the average unit times as shown in the time study Figure 13 as standard, the time for producing a lot of fifty of each job may readily be computed as follows:

Operation	Unit Time (Hours)	Total Time (Hours)					
		Job No. 1		Job No. 2		Job No. 3	
1. Procure materials..	....		4.15		4.15		4.15
2. Set drill...........	1.05	4 req.	4.20	8 req.	8.40	6 req.	6.30
3. Remove drill......	0.85	4 req.	3.40	8 req.	6.80	6 req.	5.10
4. Set jig............	2.68	once	2.68	twice	5.36	twice	5.36
5. Remove jig........	1.18	twice	1.18	twice	2.36	twice	2.36
6. Check dimensions	0.91	twice	0.91	twice	1.82	twice	1.82
7. Place work........	0.31	50	15.50	100	31.00	100	31.00
8. Drilling time......	....	37½ in. tot.	47.00	75 in. tot.	94.00	50 in. tot.	58.75
9. Mark order........	0.88		0.88		0.88		0.88
10. Clean machine.....	4.75		4.75		4.75		4.75
Total time for job	....		84.65		159.52		120.47

The advantage of thus being able to compute the time required for a given job by the process of combination of known time elements without resort to an actual operation study is readily apparent.

Time-Study Allowances.—One of the most important aspects of time-study technique, next to the actual making of observations, is the determination of allowances. Obviously, the rate of accomplishment reflected by the time observation sheet cannot be maintained hour after hour. If the standard is to be a practicable one, some additional time must be allowed. Accurate measurement of this additional time is seldom feasible, however, and there is real danger that the accuracy which may have been achieved by the observer will be destroyed by crude guesswork upon the part of the one who determines the allowances.

In making such allowances, it is necessary to distinguish between normal delays which occur more or less regularly during a day's work and emergencies which occur only at infrequent intervals. A machine, for example, may break down, thereby causing delay to the job in process for several hours. Such an emergency may not occur again for months. It has no particular relation to the job in process and probably ought not to be taken into account when determining the allowances to be made in setting the standard of accomplishment for the job. Normal delays, on the other hand, are those which normally occur during the performance of a given job. They are directly associated with the

operation and, although they may not be reflected by the time-study sheet, should be considered as part of the time of performance.

Normal delays may be classified as follows:

1. Preparation allowances—which include all such delays as those caused by the necessity of instructing the workman, procuring tools and materials, and adjusting and testing the machine prior to beginning operations.
2. Operating allowances—delays which are normally encountered because of failure of the machine, the process, or the organization, to function perfectly.
3. Personal allowances—delays which represent necessary concessions to the fact that the worker is a human being.
4. Fatigue allowances—allowances which have as their purpose the adjustment of the standard time to a pace which can be maintained by the worker without injury to health.

This classification suggests that the allowances to be made must necessarily depend upon a variety of factors. The general state of efficiency of the organization, the care observed in maintaining equipment standards, the nature of the process, climatic conditions, and the physiological characteristics of the worker, all may cause delays not reflected by the time-study sheet and must be provided for through the medium of a percentage allowance. In their final analysis allowances must always depend upon the judgment and experience of the analyst.

Insuring the Permanence of Time Standards.—Because of the uncertainty which inevitably is associated with the determination of proper allowances, it is important that all standards of accomplishment should be subjected to thorough test under actual shop conditions before they are finally adopted. Practical tests of this sort are especially necessary when the standard is to be used as the basis for piece rates. Perhaps no other factor has served to arouse so much distrust and resentment in the workman toward the methods of time study as has the hasty adoption of standards which have not first been tested under actual shop conditions. On the other hand, where thorough tests have been made and all cause for dissatisfaction has been fairly met before standards have been adopted, the interests of both workmen and management may be adequately protected.

Need for Co-operation.—The determination of standards of performance is essentially a co-operative enterprise in which both manage-

ment and workmen must participate if the results are to be worth the effort. Shop performance is dependent upon a number of things—the character of the materials, the condition of the equipment, and the nature of the shop environment. For these, management alone is responsible. But more important still is the attitude of the man at the machine or bench in the shop. Failure to appreciate the necessity of seeking the workman's co-operation has in many instances led to conditions which fully justified the criticism that, "far from being the invariable and purely objective matters they are pictured to be, the methods and results of time study and task setting are, in practice, the special sport of individual judgment and opinion, subject to all the possibilities of diversity, inaccuracy, and injustice that arise from human ignorance and prejudice."[1]

Fortunately this severe indictment need not be a permanent one. There is nothing inherent in time-and-motion-study methods which should cause a clash of interest between employer and employee. The prime purpose of such studies is the improvement of method and the establishment of standards of creditable performance. By enlarging productive effectiveness, they bring increased returns to management and workman alike, and for this reason alone they are likely to become an indispensable tool of industry.

[1] Statement made by the late Professor Hoxie in a report for the United States Commission on Industrial Relations (1916)

CHAPTER XII

METHODS OF ORGANIZATION[1]

Meaning of Organization.—Few problems of management deserve more attention than those pertaining to organization. Little of consequence is accomplished in this modern world without organized effort. No one entirely escapes this regimenting process. No enterprise, whether it be making shoes, selling bonds, promoting research, launching a political campaign, or promulgating a religion, can proceed far until the problem of organization has been satisfactorily solved. By "organization," as here used, is meant the process of classifying and correlating activities necessary for accomplishing a given desired result and of defining the personnel relationships requisite for satisfactory performance.[2]

The importance of the organization process naturally springs from the peculiar conditions created by co-operative enterprise. A "one-man" undertaking presents few problems of organization simply because all activities are performed by a single individual. It is only when several pool their resources and direct their energies toward a common goal that these problems appear. Under such circumstances, leadership becomes essential; authority and responsibilities must be defined. As the enterprise increases in size, the organization process thus begun becomes more complex. Various levels of authority are recognized.

[1] In connection with this chapter the author wishes to acknowledge indebtedness to his colleague, Professor L. C. Sorrell, whose deep study of organization has greatly influenced the author's own views on the subject.

[2] Like many other terms employed in the literature of business, "organization" has been used in a variety of ways by different writers, some apparently even using it in a sense which is practically synonymous with management or administration itself. (See W. Robinson, *Fundamentals of Business Organization.*) In adopting the foregoing definition the present writer is following Sheldon, who states that "organization is the machine of management in its achievement of the ends determined by administration." (Oliver Sheldon, *The Philosophy of Management*, p. 32.) A somewhat similar view is expressed by Hugo Diemer (*Industrial Organization and Management*, p. 1) as follows: "Organization determines the scope and limits of activity of each individual, or group of individuals in a business or industrial undertaking together with their relations and connections with one another." For a view which is different from either of these the reader is referred to H. S. Person, *Scientific Foundations of Business Administration*, p. 237.

Greater specialization is introduced. Management assumes a somewhat more impersonal character. Departments with definitely assigned duties and limits of authority are formed.

During this natural development all undertakings have many experiences in common which have given rise to certain generalizations or maxims with respect to what constitutes good organization practice. Organization in its present stage of development may scarcely be called a "science," and it is doubtful whether any such generalizations are worthy of being called "principles." Organization theory is, nevertheless, gradually assuming tangible form in the literature of the field. Some criteria for testing the relative merits of different methods of organizing a given undertaking can doubtless be agreed upon.

Since the problems presented in the organization of the production department are similar to those arising in connection with building and maintaining an organization for an enterprise as a whole, it will be well to devote some attention to these commonly accepted maxims and theories before attempting to suggest their application within the production manager's sphere.

Scope of the Organization Process.—Four steps are necessary in building an effective organization:

1. The scope and nature of the enterprise and its objectives must be clearly defined.
2. The project must be analyzed with a view to discovering the activities which must be performed in accomplishing the desired result.
3. Activities must be combined and grouped in a manner which will make it possible to assign responsibility and at the same time facilitate performance. These groups are called "departments."[1]
4. Inter-departmental relationships must be defined by designating lines of authority which are to be observed in practice.

Definition of the Objectives.—Every business unit presents a distinctly individual problem. There is no standard type or model with which all

[1] It is evident that the term "department" also may be used in a variety of ways. As used in this instance, it refers merely to any group of activities which happen to be associated for managerial purposes. Nothing is implied with reference to the relative importance of the groups thus designated. It may be a major division of the enterprise, such as the production department, for example; or may be a group within a major division, as, for example, the production-planning department, the cost-accounting department, or the assembly department.

enterprises may be made to conform. Even those in the same line of business have different characteristics. The objectives and policies of each lend an individuality which is reflected in its organizational structure. Some of these differences may be traced to the personnel factor. Individuals differ in native ability. Different backgrounds of training and experience place practical limitations upon the degree of responsibility which different individuals may safely be allowed to assume. All of these differences in ability must be carefully weighed. Each individual must be assigned tasks which he can best perform, for is it not the aim of every organization to make the best possible utilization of all available resources? But even if the personal equation might be disregarded, the fact would remain that the business unit is always formed to accomplish certain definite objectives. As these objectives vary, so also must the plan of organization be varied. It is impossible to provide the organization until we know what it must accomplish.

This is merely one way of saying that organization building and the determination of policies, which comprise two major tasks of the business administrator, are closely related. One cannot be undertaken without giving consideration to the other. It makes a vast difference, for example, in the form of organization which is required if a nationally distributed product is to be sold through the regular jobbing channels instead of by the company's own sales force. A retail business of the department-store type requires an entirely different organization of its merchandising activities than it would if it were to enter the wholesale market. An automobile manufacturer who has been accustomed to buying finished parts and assembling them only, is certain to encounter important problems of organization should he decide to undertake the manufacture of these parts in his own plant. Organization is a means to an end, not an end in itself; and the form it assumes must depend upon the job to be done.

This is just as true for the production department as it is for the business as a whole. The same sort of problems are encountered. The same principles apply. The first step in either case is to define the objectives.

The Personnel Factor.—In suggesting that activities rather than individuals should be the focal point in the study of organization, there is no intention of implying that personnel influences are of no consequence. Organization deals with human relationships, and it would be

absurd to insist that in defining these relationships the peculiarities of the individuals thus brought together need not be considered. To disregard these—to shape the man to the organization rather than the organization to the man,[1]—may result in imperfect utilization of man-power. As one experienced observer has well said,

> Usually it is not possible to set up an ideal organization and then secure the men needed to fill the various positions in this organization. You cannot secure well balanced, high grade men for all the positions in an organization. In fact, we do not have perfect men. All have weaknesses. In setting up an organization it is necessary to recognize these weaknesses and vary the type of organization so that you may take advantage of the strong points of an individual and at the same time protect yourself from his weakness.[2]

At best, organization is a compromise in which the qualifications of the men who are available for use must play an important part. In making these compromises, however, it is desirable that the task shall not be considered merely as a matter of making Smith responsible for the actions of Brown, Jones, and White, but of linking together activities which, in the nature of things, should be placed under unified control. The personnel factor is but one element to be considered. To ignore all else is almost certain to result in illogical developments which must be rectified by disruptive reorganizations whenever key men leave the enterprise.

Analysis of Activities.—Organizations differ not so much because each deals with a different set of activities as because these activities vary in relative importance under different circumstances. Nearly all business enterprises, for example, find it necessary to keep some sort of record showing amounts due from customers. This particular activity of accounting for "receivables" is common to all, but its relative importance is much less in a retail store where cash transactions predominate than in a large instalment-selling house. All manufacturing companies have certain planning activities to perform. But much less effort is required in planning the day-to-day operations in a flour mill which manufactures a single standardized product than is required in a machine-shop fabricating many highly specialized products. Production planning accordingly occupies a much less conspicuous place in the plan of organization of the former than of the latter. Every manufacturer

[1] L. Galloway, *Factory and Office Administration*, p. 118.

[2] J. O. McKinsey, "Sixteen Trends of Management," *Publications of the American Management Association*, p. 13.

must give some attention to the designing of his product. In some instances this activity becomes so important that it is the task of a major department. In others it is merely one of the many activities for which the production manager is responsible. Many activities are common to all organizations. But there are wide differences in the manner in which they are combined into groups or departments and in the relations maintained between different departmental units.

The real problems of organization thus are concerned not so much with discovering what activities must be performed as with what combinations of these activities in administrative units will best serve the ends in view. This process of departmentation is perhaps the major issue to be considered when formulating any theory of organization. It includes both the combination of activities in coherent groups called "departments" and the laying-down of "lines of authority" by which inter-departmental relationships are maintained. Variations in these respects constitute the chief distinguishing characteristics of the different "types of organization" so often referred to in the literature of the field.[1]

The Basis of Departmentation.—These so-called "types of organization" are distinguishable chiefly because of fundamental differences in the "basis of departmentation." To be specific, one rarely, if ever, encounters an organization which illustrates any single type in its pure form. What one does find, and doubtless what most writers mean when referring to different types, is that every organization is composed of departments in which a given basis of departmentation predominates.[2] In fact, all organizations save those of the most rudimentary character comprise departments formulated upon different bases. All that can possibly be meant by a functional or a territorial organization, for

[1] The types most frequently recognized by writers on the subject have been (1) line, (2) line and staff, and (3) functional, although these have sometimes been defined in somewhat different terms. See D. S. Kimball, *Principles of Industrial Organization*, pp. 93–102. A. G. Anderson, *Industrial Engineering and Factory Management*, p. 44, recognizes a fourth type, which he calls "the committee plan of organization." This may properly be regarded as a hybrid, since the committee is a valuable managerial aid more or less employed in all modern organizations regardless of type.

[2] That this deficiency in organization terminology has sometimes been recognized is indicated in the following quotation: "With the growth of industry several distinct types of organization have been evolved, each with its particular merits. They will be analyzed separately, although in practice two or even several forms will be found combined in a single organization structure. The dominating type varies according to the character of the industry, the size of the concern, the abilities of the available personnel and the idea of the management." (A. G. Anderson, *op. cit.*, p. 39.)

recognized. Administrative departments often represent some form of specialization. Sometimes the specialization is territorial in character, all activities of a given kind which happen to be associated with carrying on the business within a given geographical area being grouped together in a separate administrative unit. In other instances, activities which are identified with different commodities in which the company deals are combined in separate departments, thus giving rise to a form of commodity specialization. Still again, the limits of the department may be determined by grouping together all activities which originate in connection with transactions with a special group of customers of the concern. This may, for the sake of convenience, be called "customer specialization." Perhaps the most common of all forms of specialized departmentation (though by no means the easiest to define satisfactorily) is that resulting when activities identified with a given process, as contrasted with other processes of the enterprise, comprise the departmental unit. Thus, sales activities are grouped together in a sales department or production activities are combined to form a production department. Such departments illustrate what is often referred to as "functional specialization."[1]

Some Non-specialized Forms of Departmentation.—In some organizations, however, little or no specialization as between departments is apparent. The activities to be performed are relatively simple. Very little division of labor is possible. The necessity for effecting co-ordination between individual workers is reduced to a minimum, and the chief problem of management becomes the maintaining of effective discipline. A classic illustration of this sort is cited by Robb in his description of the methods employed in constructing an earthen dam in India.[2] The task in this instance consisted of carrying earth in baskets and depositing it at the proper place upon the dam site. Hundreds of workers were employed at identical tasks. The performance of each in no way depended upon the performance of others, but strict discipline

[1] As we shall see presently, the term "functional specialization," as applied to organization, has not always been defined in the same way.

[2] R. Robb, *Lectures on Organization*, p. 10.

was essential. The workers were accordingly organized in groups of from twenty to thirty. A foreman was placed in charge of each group and was in turn made responsible to the superintendent of the work. There was no division of labor either as between individual workers or as between groups. Each foreman occupied the same level of importance as every other foreman. The actions of one group in no way depended upon the actions of other groups. The authority and responsibility of each foreman was clearly defined, being delegated by the superintendent above and extending only to those workers in the ranks over whom the foreman exercised immediate jurisdiction.

Such administrative units may scarcely be called departments—a better name would be "gangs." They involve no specialization and are necessary merely because the work to be done requires a larger labor force than can be effectively supervised by a single overseer. In general pattern, this most elementary form of organization follows very closely that of the army as exemplified in the infantry regiment.[1] Naturally, such simple methods of organization have little real significance with reference to industrial operations. The processes of modern industry are ordinarily much more complex and in no way comparable to the crude enterprise which Robb describes. As complexity increases, minute divisions of labor become more fruitful. The non-specialized gang must give way to the specialized department as the administrative unit. The direct and clearly defined lines of authority which characterize the gang organization must be modified to permit the introduction of specialists and staff executives.

The chief application of the gang organization under modern conditions must necessarily be confined to the lower levels of operations in the production department. Here, workers who are employed at identical tasks are sometimes organized into gangs in order to insure more intimate supervision or stricter discipline.[2] The size of the gang is de-

[1] This similarity has been remarked by most writers on organization, who have called this the "line" or "military" type of organization. (D. S. Kimball, *op. cit.*, pp. 93–94.) Its applicability even in the army is limited to the internal organization of the regiment. In the organization of an army division, specialization in the different branches of the service is invariably recognized; and as military tactics become more involved, this same specialization tends to be introduced even within the regiment itself.

[2] An illustration of this plan may be observed in large textile mills, where the operators of huge batteries of looms or spinning frames are sometimes organized in this fashion as a means of securing more effective control. Railway maintenance forces or "extra gangs" are also commonly organized in a similar way.

termined by the number of individuals whom a single foreman can effectively supervise.

A somewhat similar problem of organization is presented where a number of shifts are employed. A foreman's jurisdiction must usually be confined to the time he is on duty. His relations with his subordinates are of too intimate a character to permit of his duties being performed *in absentia*. In the lower levels of authority, at least, it is necessary to provide foremen for each shift. In making such provisions no new problems are presented with respect to the organization of activities, since presumably the duties of the night shift will be similar in character to those of the day shift. In so far as organization is a matter of providing effective supervision of individuals, however, the situation is complicated by the introduction of the extra forces. To what extent, for instance, must the supervisory forces be duplicated? In striving to answer this question, conflicting issues are likely to be encountered. There must at all times be an executive in immediate charge with sufficient authority and capacity to deal with emergencies as they arise. On the other hand, the activities of day and night forces must be co-ordinated. The lines of authority extending upward from foremen in charge of different shifts must converge in the hands of a single executive at the lowest possible level. Otherwise, different shifts may find themselves to be working at cross-purposes. The problem thus presented is one concerning which generalizations cannot be made. Its solution in any case must depend chiefly upon the nature of the process and the capacity of foremen for assuming responsibility during the absence of their superiors.

Territorial Departmentation.—The practical limits of any executive's jurisdiction depend upon the nature of the supervision which he must exercise. The relations of a foreman to his men are so intimate that his special bailiwick must always be strictly limited. The junior executive's supervision is less detailed in character, and in consequence he may perhaps be given authority over several foremen. The executive of a major department exercises still less intimate supervision, which accounts for the fact that he is able to direct a major division of the business. Finally, the general manager is concerned with operating details scarcely at all. His particular interest is centered in broad questions of policy and the co-ordination of the efforts of his subordinates. By confining his attention to this level, he is able to exercise control over the entire enterprise, which may perhaps extend over a wide area and employ thousands of men.

In a small business with few employees the task of management is not an irksome one. It is neither extensive nor intensive, and a single executive may easily assume the entire burden. As numbers increase, the limit of any executive's capacity for assuming complete responsibility is soon reached. Some division of executive activity must be made. The gang which has just been considered represents the simplest type of administrative unit. The shift represents another basis of division. Both may be employed in the same organization, but their origin is traceable to different causes. Whereas the gang owes its existence to the fact that there are more workers than can be supervised by one foreman, the shift is the product of continuous operations. The basis of the first is mere numbers; the second represents a division on a time basis. Neither represents an administrative unit of very high order.

In the modern organization, such simple divisions no longer suffice. New bases of departmentation have become necessary, and interdepartmental relationships are much more complex. Nothing has contributed more to this growing complexity in organization than the development of large-scale enterprise. The railway company which was once measured in hundreds of miles now is measured in thousands. Public utility companies often operate in a dozen or more states. Manufacturing companies not infrequently own and operate a series of plants extending from the Atlantic to the Pacific and even to foreign shores. Many sales organizations are national in scope. Chain stores, brokerage houses, and even professional-service agencies are constantly extending their several spheres of influence by establishing branches which sometimes are far removed from the home office.

This decentralization has introduced new problems of management. The number of employees has greatly increased, but mere numbers alone do not determine the boundaries of the administrative unit. There are territorial limitations to the capacity of executives also, and expansion has been marked by the introduction of departments based upon territorial distinctions. The territorial administrative unit itself is, of course, not new. Man's political activities have been so organized almost universally ever since national boundaries were first recognized at least. Its adoption by modern industry is due to an analogy. Industrial expansion has created a business unit which in many respects closely resembles the political unit. It is but natural, therefore, that industry should borrow from the latter the form of organization which

centuries of experience have shown to be the practical one under the circumstances.

Like all administrative units, the territorial department represents a concession to the physical limitations of executive capacity. There is a limit to the area over which one man can extend his personal influence. If the supervision required of an executive is of very intimate character requiring close attention to minute details, this area must be very narrowly restricted. If the demands made upon the executive's attention are more general in character, a wider area may be covered. This is neatly illustrated in the maintenance-of-way forces of railway organizations. A track foreman must inspect his territory daily and is directly responsible for the minutest details of its upkeep. In consequence, a dozen or so miles of track, usually called a "section," represent the maximum limit of his capacity. A roadmaster's supervision is more general in character, since he may delegate responsibility for many details to the foremen under him and thus his jurisdiction may include a score or more sections. In the division superintendent, supervision both of maintenance of way and operating activities is combined in a single executive; but because he is relieved of many details which are delegated to his subordinates, responsibility for several hundred miles of line is not an excessive burden. This process of combination continues in the higher levels of authority. Divisions are combined to form districts; several districts may constitute a grand division; several grand divisions may constitute the system, in which all lines of authority converge in the office of the president himself. As one approaches the higher levels of authority, the executive's personal contact with the properties necessarily becomes more remote, until, when the president is reached, it may chiefly consist of an inspection trip once or twice a year undertaken principally for the wholesome discipline which the chief executive's presence on line engenders in his subordinates.[1]

[1] That purely physical limitations are thought to be important even on the chief executive's level is indicated in the following statement made by President Thornton of the Canadian National Railways: "It is true that the Canadian National Railway System comprises more than twenty-two thousand miles of line, but over a large portion of the territory traffic is relatively sparse. Even at that, however, for the executive to cover the territory and keep in touch with various local and national interests passes the power of circulation be it ever so rapid. . . . . I deprecate the formation of systems so large as to pass beyond the administrative scope of the head of the system." (Published address delivered before a joint conference on education and industry under the auspices of the University of Chicago and the Institute of American Meat Packers, October 22, 1924.)

The territorial unit is especially advantageous when emergencies arise. At such times someone must be immediately available who by training and authority is able to assume sole charge and to issue whatever orders are necessary to restore normal conditions. A branch manufacturing plant, for example, might be controlled directly from the home office when everything is running smoothly. But let a breakdown occur, labor troubles develop, or materials be delayed—both quantity and quality of output are immediately endangered, and there must be someone at the plant itself who has sufficient authority to bring order out of chaos. Remote control in time of emergencies is, of course, rendered less deficient by improved methods of communication. The telephone, for instance, has rendered a distant branch much less isolated than it necessarily was before this invention. All of our modern facilities of communication, however, provide but a poor substitute for the personal contact of a single strong individual with power to act when action is required.

It is just such conditions as are created by emergencies when a young subordinate is thrown upon his own resources that uncover potential executive capacity. The territorial department perhaps supplies a better training school for future general executives than any other type. Its varied activities present in miniature a cross-section of the entire enterprise, or at least of a major division of the enterprise, and thus enable the junior executive to secure a broader experience than would otherwise be possible.

Still another justification for territorial departmentation arises from the fact that different territories often present different problems of management. The problems of distribution in a highly developed urban district may be entirely different from those in a sparsely settled region. Track maintenance and train operation upon a prairie division of a railway require a different type of experience than is demanded upon a mountainous or a congested terminal division. The labor problems with which a plant manager must deal in one region may be entirely different from those in another region, even though the plants are in other respects identical. Such differences suggest the possibility of specialization which undoubtedly in many instances is the prime motive behind the territorial basis of departmentation.

Customer Specialization.—But there are still other bases of departmentation. Business enterprises depend for their existence upon the

patronage they receive. The customer must be satisfied; and since different groups of customers have different needs and must be approached in different ways, it is to be expected that customer groups should exert some influence upon the organization which is striving to serve them. Specialization in terms of customer groups naturally is confined to those spheres of activity within the organization, such as the sales and collections departments, which touch directly these customer relationships. It is rare indeed, for example, for any subdivision of production activities to be influenced by a need for customer specialization. "Special-order" departments are sometimes found within the production division, it is true, but these divisions are observed not because of the customer's influence but because special orders entail specialized methods of production. In other words, the commodity itself is different.

In the sales division the customer basis of departmentation is much more common. In fact, the division of a merchandising business into wholesale and retail departments is nothing but a type of customer specialization. The same merchandise may be bought and sold by both departments, and the distinction is explained by the different habits of retail and wholesale customers. This basis of departmentation invariably represents a form of specialization. Where it is employed, it must be explained and justified on these grounds.

Commodity Departments.—The commodity basis of departmentation is much more generally employed. Production of one commodity often involves a group of activities which are unrelated to the production of other commodities. Different materials are derived from different sources and necessitate familiarity with different market practices. Efficient buying and selling are dependent upon a knowledge of commodity characteristics. To be acquainted with the properties of one commodity does not necessarily qualify a buyer to deal in another. One might, for example, spend years in acquiring an expert knowledge of linen textiles; this special talent virtually would be wasted if one's attention were to be diverted to the buying of drug products or of leather. The importance attached to specialized knowledge of commodities and commodity markets is the chief reason why commodity specialization occupies so prominent place in the internal organization of purchasing departments. It explains the peculiarities of department-

store organization and why railways invariably have separate freight and passenger traffic departments.[1]

In the production department also, commodity differentiations are not uncommon. Meat-packing-plant operations, for example, usually are divided into three divisions: the provision or pork department, the beef department, and the small stock department devoted to the preparation of veal and mutton. An automobile manufacturer, to cite another common example, may include within his plant organization a separate coachwork department, a radiator shop, and a wheel department. The factor which distinguishes each of these departments is the commodity which they produce. Special methods which no other department employs are required in each instance. Special skill is demanded of those who are employed in these departments, and these specialized activities are accordingly brought under unified control.

Often in the production department the executive in charge of a commodity division is made responsible only for those activities which are peculiarly associated with the production of the commodity in question. Activities which are common to the production of all commodities are removed from his jurisdiction and are organized for the entire plant upon some other basis. Thus, in the automobile plant just cited, the procuring, storage, and issue of materials comprise activities which must be performed in the manufacture of each of the three commodities mentioned. The planning of operations comprises another group of activities which is common to all, and the inspection of the finished product constitutes a third. Under the circumstances it is probable that these activities would be organized in three separate departments, called "stores," "production planning," and "inspection," the executive in charge in each case being made responsible for his specialty throughout the plant.

Commodity lines of cleavage are not ordinarily recognized as the primary basis of departmentation in the production manager's sphere, as they virtually are within the merchandising division of a department store. In the rare instances where this condition does exist within the production department, it is likely to be the result of special considerations such as, for example, the production of each commodity in

[1]The traffic departments of a railway correspond to the sales department of a trading business. Traffic is a service rather than a commodity; but this distinction is, for our present purpose, immaterial

a separate plant. In this case, territorial as well as commodity distinctions may be responsible for the method of departmentation.[1]

Functional Organization.—The bases of departmentation which have been considered thus far are more or less objective in character. In general, they have received much less attention from students of organization than has the so-called functional organization. Departmentation upon the functional basis implies the classification of activities according to differences of function in contrast with territorial, customer, or commodity differences which characterize other bases already discussed.

This distinction can best be made clear by means of a concrete illustration. Suppose, for example, that a company is to be organized for producing and selling several commodities in the national market. A number of plants in different parts of the territory have been acquired; a chief executive has been selected; and the question has arisen as to the basis upon which responsibility should be divided among his immediate subordinates. Several possibilities suggest themselves. One is to classify activities according to functional differences. Upon analysis it is found, for instance, that there are certain activities associated with the carrying-out of the financial policies of the enterprise. Others are associated with the production of finished goods; others with the purchase of materials; and still others with distribution of the product. These are functional differences, and the classification of activities upon some such basis is what is ordinarily implied by the term "functional organization."[2]

But there are other possibilities. The territory to be served may be divided into regions, and an executive may be placed in full charge of

[1] The International Harvester Organization is perhaps a case in point. Tractors, harvesting machinery, and motor trucks are manufactured in separate plants and under what appear to be practically independent divisions of the production department. Historical factors may, in part, explain this situation; and certainly territorial limitations, as well as commodity distinctions, must also exert an influence in situations of this magnitude.

[2] This particular classification of activities results in the formation of departments which strongly resemble those found in what some writers have called "the departmental type of organization." Hugo Diemer, for instance, in describing the "departmental type" says "In the administration field of business we find the principle of specialization first appearing in the division of management under three headings, namely, producing, selling and accounting." (*Industrial Organization and Management*, p. 8.) Later writers, including McKinsey, Briscoe, and Robinson, have called this "functional organization." It should be noted, however, that this is not the same "functionalization" as that of Frederick Taylor.

each. By such a plan he would be responsible for all functional activities, including production, distribution, financing, accounting, within his own territory. All of these activities would be common to all divisions but would be completely severed from one another at the territorial boundaries. A third method would be to recognize the commodity basis of division, making one executive responsible for all activities throughout all territories for one commodity.

The lines of cleavage dividing one major department from another, always more or less arbitrarily drawn, in the latter instances might represent merely an attempt to reduce the administrative unit to such proportions as would bring it within the administrative scope of the executive in charge. In so far as this were true, the considerations determining the boundaries of each department would be identical with those determining the scope of the foreman's jurisdiction in the rudimentary "gang" organization already described. As in the case of the gang also, all departments would have many activities in common.[1]

Functional Foremanship.—It was this multiplicity of activities within a single executive's jurisdiction, so typical of these objective bases of departmentation, which early advocates of a functional classification sought to avoid. Frederick Taylor is credited with introducing the term "functional organization"; and while his own thinking upon such matters apparently was chiefly confined to the lower levels of authority within the shop, the principle of functional foremanship which he enunciated has much wider application than may at first appear.[2]

Upon analyzing the task of the "old-fashioned foreman,"[3] he discovered so many qualifications to be necessary that, to use his own words, "no man can be found who can satisfactorily perform all the

[1] The analogy between the "gang" and the commodity or territorial department is not complete, for, as has previously been pointed out, both of these latter types often involve some degree of specialization. This specialization arises from the fact that different local conditions within a department make it necessary for the personnel in each case to acquire specialized factual skill even though all perform identical activities. It differs from that of a functional executive, since in functional departments the activities themselves are different.

[2] Taylor's views are summed up as follows: "Functional management consists in so dividing the work of management that each man from the assistant superintendent down shall have as few functions as possible to perform." (*Shop Management* [Harper & Bros., 1911], p. 99.)

[3] He thus distinguished between the methods of shop organization in vogue in his day and the functional foremen which he advocated. (*Ibid.*, pp. 96–98.)

duties required of him." Whereupon, he classified these activities in eight groups, which in turn were equally divided upon two levels which he called "planning" and "performance." This classification is shown in Figure 14.

Each group represented the sphere of a functional foreman; and thus, as he said, "the old-fashioned single foreman is superseded by eight different men, each of whom has his own special duties, and these men,

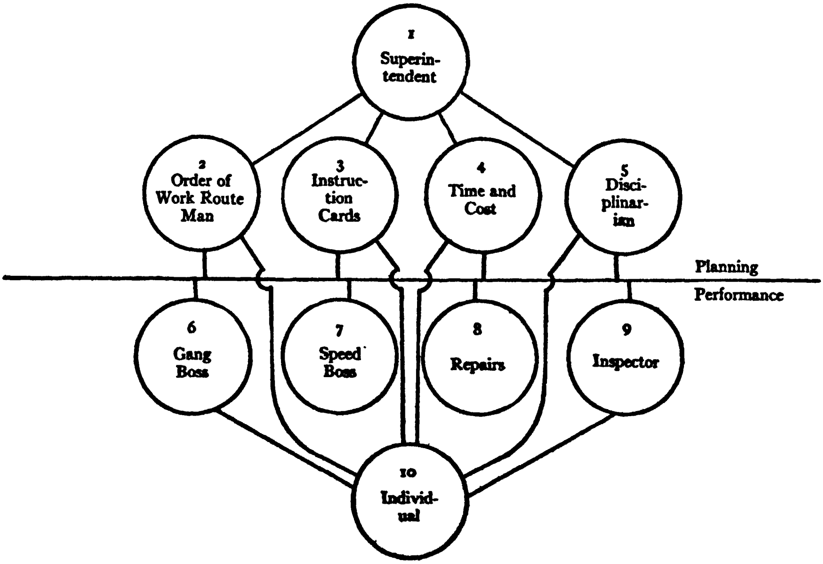


FIG. 14.—Showing scheme of functional foremen as proposed by Frederick Taylor. (Adapted from a diagram by F. B. Gilbreth, "Units, Methods and Devices of Measurement under Scientific Management," *Journal of Political Economy*, XXI [1913], 619.)

acting as agents of the planning department, are the expert teachers who are at all times in the shop helping and directing the workmen."

Obviously, this constituted a radical departure in the organization of the shop. To adopt this suggestion would be to disregard the old and often arbitrary departmental distinctions within the shop and to set up in their place these specialists each of whom would direct some special phase of shop work. Instead of each workman having one boss, he would now have eight. The effect of these changes, in so far as lines of authority are concerned, is readily seen by comparing the charts shown in Figures 15 and 16.

This multiple division of authority is the chief defect of the plan. The line separating the field of one functional specialist from that of another is often an exceedingly fine one. Embarrassing questions of jurisdiction are almost sure to arise. Such issues cannot be entirely avoided, it is true, in any plan of organization. But it is possible, nevertheless, to

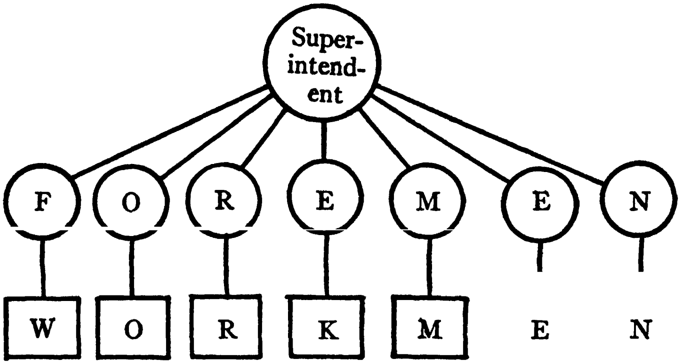


FIG. 15.—Diagram showing non-functional foremen with line authority only

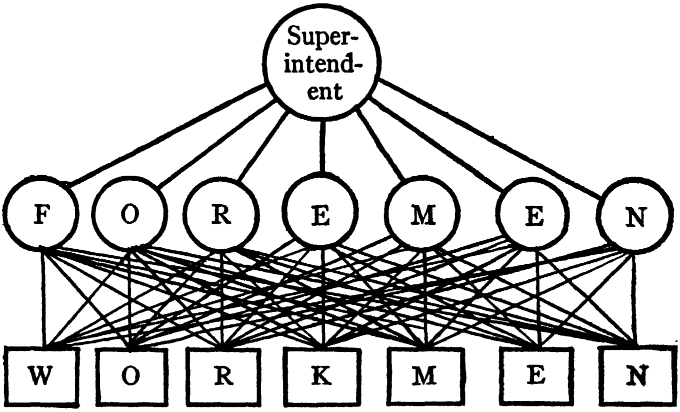


FIG. 16.—Diagram showing functional foremen with line authority only

insure that they shall be dealt with on the managerial level, not in the shop. Opponents of the plan have insisted that to make the workman directly responsible to more than one boss inevitably draws him into the controversy whenever the bosses cannot agree. Conflicting orders are likely to be issued, and he is placed in the dilemma of choosing which shall be obeyed. Such situations needlessly endanger morale and

quickly breed contempt for authority. This was a serious objection, and apparently few attempts have been made to apply this idea of functional specialists with line authority upon the higher administrative levels in the organization.[1]

In spite of this fatal weakness, however, Taylor's contribution to organization theory was a substantial one. He it was who first insisted that the principle of specialization applied to management as well as to work at the machine or bench in the shop. His contention that there should be a separation of planning and performance, in so far as is physically possible, has been accepted as fundamentally sound by everyone. What he failed to make clear was that there may be more than one kind of relationship existing between executives and their subordinates. Later writers, by introducing the concept of functional authority in addition to line authority, have been able to devise a plan of organization which preserves these valuable features and at the same time avoids the multiplication of bosses.

Two Kinds of Authority.—The distinction between line and functional authority is important. An executive is said to exercise line authority over subordinates when he is responsible for seeing that they perform the duties assigned to them. On the other hand, his authority is said to be functional when his responsibility extends merely to specifying *how* these duties shall be performed.[2] Executives with functional authority only are usually specialists. Thus, while each workman is responsible to a single line boss, he may receive instruction from several functional supervisors. An illustration or two will aid in making this relationship clear. In the modern production department, the routing and schedul-

[1] A. H. Church, in the *Science and Practice of Management,* does suggest a functional classification of production activities which is reminiscent of Taylor. He lists five "functions," including: design, equipment, control, comparison, and operation. Sheldon, who probably was somewhat influenced by Church, in the *Philosophy of Management* gives a somewhat similar classification, not wholly pertaining to production, including: preparation, production, facilitation, and distribution. It is perhaps not unfair to either of these writers to suggest that their functional classifications were proposed not so much as a basis of departmentation as an analysis of business activities which facilitated discussion. Sheldon, in particular, specifically condemned the Taylor idea on the grounds already mentioned.

[2] J. O. McKinsey defines "functional authority" in the following terms: "An executive has functional control of an activity when he is responsible for working out the plan, method or procedure by which the activity is performed. He may have both line and functional control of an activity, or he may have line control and not functional control and vice versa." (*Managerial Accounting,* I, 13.)

ing of work and the preparation and issuing of instructions to the shop is often the responsibility of a production-planning department. An engineering department determines standards of quality and prepares specifications as to how the work must be performed if these standards are to be maintained. An inspection department is provided which is responsible for detecting violations of these standards. Perhaps a representative of the personnel department interviews and hires the prospective worker, introduces him to his job, and seeks to effect adjustment in case he proves to be a misfit.

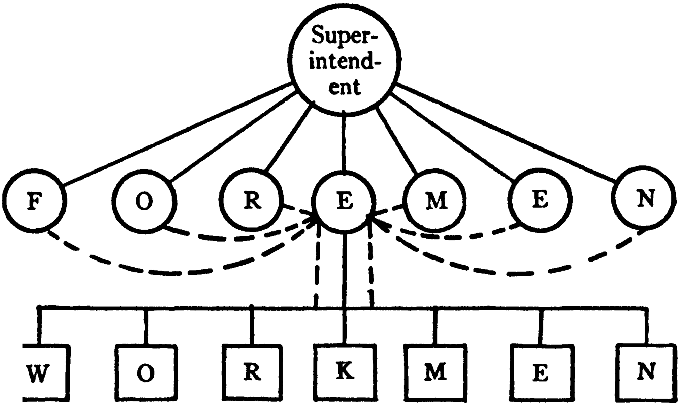


FIG. 17.—Diagram showing line foreman with line authority and functional foremen with functional authority only.

All of these were responsibilities of the "old-fashioned foreman" of Taylor's day. It was these which he proposed to assign to his functional foremen. In the modern organization, these activities are the special responsibility of executives whose authority over the man in the shop is purely functional. The latter has but one boss, his foreman, who has sole responsibility for enforcing the instructions of functional executives. The fundamental difference between this and the older plans is readily seen by comparing Figure 17 with Figures 15 and 16 already mentioned.

Thus, by the introduction of the concept of functional authority, the chief merit of the functional-foremanship plan, namely, the employment of specialists for special tasks, has been preserved. At the same time, its most serious defect has been avoided. Jurisdictional disputes

may still arise between line and functional executives. They are settled on the executive level by appeal to their superior, however, and thus do not embroil the worker, as was almost inevitable with the older plan.

The concept of functional authority is applicable in all departments of the organization. The chief accountant, for example, has line authority over the accounting department. He may, at the same time, exercise either line or functional authority over the accounting forces in a distant branch office. Where his authority over branch accountants is functional only, the line authority is, of course, exercised by the branch manager. The financial executive may occupy a similar position with respect to collections and disbursements when these activities are decentralized in a branch-house organization.[1]

The authority exercised by some major executives is nearly altogether functional. The personnel manager may, for example, possess little line authority except over his immediate staff but may exert an important functional influence throughout the organization by virtue of his authority to formulate personnel policies.[2] Much of the controller's authority, where that executive is intrusted with the design and supervision of budgetary and office procedures, is also purely functional. In some instances his authority in this direction extends only to the power of approval or rejection of the methods or procedures which other departments propose. Such limited authority has, of course, as its chief purpose the assurance that procedures which may affect the interests of several departments shall be reviewed by someone who is in a position to appreciate these varied interests. This insures co-ordination between departments.

[1] Some authorities employ the terms "centralized" and "decentralized" to describe these two possible situations. Where, for example, the chief accountant exercises complete line authority over all accounting activities, this group of functions is said to be organized on a centralized functional basis (even though performance may be decentralized); where part of such activities are under the line control of executives of other departments but under the functional authority of the chief accountant, the department is said to be of the "decentralized" functional type.

[2] In this illustration we have what seems to be the essential feature of the so-called "line-and-staff" type of organization which most writers on organization describe. C. B. Going, in speaking of this type, says, for instance: "Every complete organization must embody the principles of both line and staff if we are to secure the best results, the staff supplying expert functional guidance, applied through the line's direct control." (*Principles of Industrial Engineering*, p. 43.)

The Functional Basis of Departmentation.—In the illustrations which have been cited, the tacit assumption is that the major basis of departmentation within the organization shall be functional in character. Accounting, sales, finance, and production, to mention but a few instances, are commonly recognized administrative divisions based upon functional differences. Each constitutes a fairly homogeneous and readily distinguishable group of activities. The ultimate purposes or objectives of all such departments are identical; their immediate objectives are entirely different. In performing the record-keeping function, the accounting department's activities are readily distinguishable from those of other departments. The finance department includes all activities associated with the formulation and enforcement of financial policies. Production activities are not difficult to distinguish from those of other functional groups. Sales activities form a distinct group because of their association with the processes of distribution.[1]

The general boundaries of these major functions are in each case rather obvious. It is not always so easy to determine, however, just what activities should be included in a functional department. Most writers have been content to define a function as a group of similar activities, but this definition is not particularly helpful unless we know in what respects they must be similar. On this aspect of the definition very little light has been thrown. Analysis of functional departments in practice soon reveals the fact that there is no single basis of similarity which may be applied. As already suggested, the particular combinations of activities which ordinarily comprise the major functional departments of an organization are explained by a similarity of purpose. This element of similarity explains many of the subdivisions within these major departments as well. In the production department, for example, one frequently finds such subdivisions as stores, maintenance, buildings and grounds, tools, plant transportation, and power. Each of these departments has a different purpose, though all contribute to the

[1] It is worth noting that all of these functions represent generic divisions of the organization's activities in contrast with the specific divisions which Taylor, Church, and Sheldon evidently had in mind in their special use of the term "function." These functional departments each represent a group of activities which are related to a given process. In the special sense in which the writers mentioned above have used the term, on the other hand, a function is an element or single activity which is common to all processes. "Planning," "comparison," and "facilitation," for example, are activities which are common to all administrative divisions of the organization. As a matter of fact, in the modern organization both types of "functionalization" are often recognized.

common objective of producing finished goods. It is unity of purpose which, more than anything else, determines what activities shall be included in each of these departments.

There are, however, other points of similarity which often are recognized. Each department is an administrative unit for which some one individual must assume responsibility. But individuals have limitations and perform most efficiently when opportunity for specialization is afforded. Some possess in marked degree the attitude of mind and special qualifications required of successful salesmen. Others are better qualified for work in the production department. Still others possess the judicial attitude of mind and the painstaking regard for details which mark the statistician. Some activities are similar in that they require similar attitudes and qualifications, and thus are likely to be found in combination within the same functional department. By the same token, some are dissimilar and are accordingly seldom found within the same administrative unit. The salesman and the credit man are, for example, almost sure to feel a clash of interest, and for that reason seldom can be placed in the same department. On the other hand, the salesman and the advertising man have much in common, and this accounts for the fact that these activities are often placed under unified control.

The influence of individual limitations is discernible in other departments. Some activities are similar in that they require the same methodology. This undoubtedly is the chief justification for providing unified control over such techniques as statistics, accounting, or product design. Technical experts are required for these tasks, and the advantages of specialization are obvious. In other instances activities are similar not so much because they employ similar methods as because those who perform them must have access to the same information. The traffic expert and the legal adviser are specialists not because of their methods but because of the specialized information and experience which they possess. Skill in performing these activities is not readily acquired, and specialized departments must be provided if satisfactory performance is to be secured.

There is still one other consideration which apparently has some influence in determining what constitutes a function. Sometimes activities are so intimately related that they must be placed under centralized authority (in spite of obvious dissimilarities) in order to insure responsibility for the performance of any one of the group. The develop-

ment of production standards is a case in point. The standards for the finished product often depend upon standards of performance required of the worker, upon equipment standards, upon standardized working conditions, and upon standardized quality of raw materials. The research required to determine these different types of standards differs widely, but they are all so intimately related that centralized control may be desirable. The same arguments may be advanced in justification of a centralized inspection department having responsibility for maintaining all production standards.

Characteristics of a Good Organization.—The foregoing discussion of various bases of departmentation is largely descriptive. No attempt has been made to argue their relative merits. Indeed, such a comparison, if attempted, would likely prove fruitless. Each basis has its own particular sphere of usefulness. The desirability of an organization must not be judged by the basis of departmentation which predominates, but by the degree to which the several bases employed are adapted to the work in hand.

There are, however, some characteristics which are common to all good organization:

1. *Lines of authority must be clearly defined:* The importance of this requisite is obvious. Every worker must know what his duties are and to whom he is responsible. This is, of course, the prime purpose of all organization.

2. *Lines of authority should in all cases be undivided:* The dangers of divided responsibility have already been mentioned. In business as well as army organization there must be "but one channel of command."[1] Recognition of functional, as well as line, authority has made it possible to preserve this ideal and at the same time secure specialization in management.

3. *Executive responsibility and authority should be coequal:* This is axiomatic. To exact responsibility where no authority has been granted is intolerable and certain to destroy executive morale. One can scarcely be held responsible, for example, for expenditures which one does not authorize, nor can the performance of one executive be judged by conditions which are controlled by another. The converse is true also, of course, for to permit the exercise of authority without enforcing responsibility is not organization but anarchy.

[1] Col. R. H. Allen, *The Organization of the United States Army*, p. 44.

4. *Suitable checks and balances should be maintained:*[1] This requisite implies that those whose duty it is to check performance should not be responsible to those whose work is being checked. Perhaps the best illustration of this requirement in the production department is afforded by those who are responsible for maintaining quality standards. Inspection is a judicial function. Independence of judgment is essential, but cannot be preserved when inspectors are responsible to foremen whose work is under scrutiny. The foreman often is between two fires. He is urged to maintain quantity production at minimum cost and in consequence may neglect to give sufficient attention to quality if this independent check is lacking.

Accountants have made much of this principle, since the accounts themselves function as a check on performance. It would, for example, be regarded as poor practice to make the same individual responsible for the custody of cash and the cash record. The stores department which is responsible for safeguarding materials should not also be responsible for maintaining the balance-of-stores record. The purchasing department's approval should not be taken as final authorization for payment of vendors' invoices; neither should the sales department be responsible for making decisions concerning the extension of credit to prospective customers. Judgment in such instances is likely to be biased or tinged with self-interest, and decisions of this nature should be made by disinterested and independent executives.

5. *The number of subordinates reporting to any executive should be limited:* The natural tendency as business organizations increase in size is to multiply administrative units, thereby increasing the number of subordinates who report directly to responsible executives. Just as there are physical limitations to the territory in which one executive can supervise operations, so, also, there are practical limitations to the number of subordinates he can effectively direct. Men of wide administrative experience are especially insistent upon the correctness of this view.[2] How many administrative units one executive can direct de-

[1] One must, of course, be cautious in advocating this. Too great emphasis upon checks and balances may make co-ordination difficult and lead to a situation where no one knows who is responsible. Whereas such conditions may perhaps be justified in governmental affairs, they cannot be tolerated in the business enterprise.

[2] This idea has been particularly well expressed by Ian Hamilton in *The Soul and Body of an Army*, p. 230. See also, J. O. McKinsey, "Sixteen Trends of Management," *op. cit.*, p. 11.

pends, of course, both upon the individuals and the nature of the activities over which they have jurisdiction. It is probable that most authorities would agree that, under ordinary conditions, to make an executive responsible for only two or three subordinates would constitute a needless degree of supervision, whereas the presence of nine or ten would constitute the maximum limit under most circumstances.

6. *An organization should aim to make the best utilization of human resources:* This statement is merely common sense. The most serious charge that can be laid at the door of management is inefficiency. To waste materials, to fail to make the most of the existing plant, to neglect opportunities for profit-making—these are deficiencies for which management alone must assume responsibility. But man-power is just as important as materials. To place a man where his natural abilities are not fully realized may be just as unprofitable and much more serious from society's point of view than the waste of materials. On the other hand, to give a man more authority than he is able rightly to exercise is like attempting to make a high-grade product from poor materials. Successful organization calls for careful study of the human resources. It is not a cold mechanical process. Men must be given an opportunity to grow, or else they will lose interest and leave the organization. But all men have weaknesses as well as points of strength, and the organization must be protected from these weaknesses.

7. *An organization should strive to be self-perpetuating:* The weakness of the "strong-man organization" lies in the fact that it is not self-perpetuating. Everything may run smoothly for a time. It may even be more efficient than its competitors. But remove the key man, and reorganization is immediately necessary. As Oliver Sheldon has said, "Positions should be so graded as to allow a methodical progression from one to another."[1] Everyone in an organization ought to be in line for promotion. Every man should be encouraged to regard himself as an understudy of the man higher up.

New blood must, of course, be introduced. Often new activities are added for which no one in the organization has adequate training. Occasionally, a major executive is brought into an organization from a competing company, or even from an entirely different line of business, with striking results. An outsider, unfettered by petty jealousies and rivalries, sometimes succeeds where an equally capable man who has

[1] *Op. cit.*, p. 143.

long been associated with the organization might fail. Such instances are, however, probably exceptions. They are themselves an admission of weakness, as the chief executive of a large railway system clearly saw when several years ago he remarked: "I would consider my organization a failure if I found it necessary to go outside for a new general manager." The policy of habitually making additions at the top deadens the initiative of subordinates, injures morale, and may alienate much of the best potential talent in the ranks.

CHAPTER XIII

ORGANIZATION OF PRODUCTION ACTIVITIES

Nature and Scope of the Production Department.—In the last chapter various methods of departmentation were discussed. An attempt was made to determine what must be considered when formulating a plan of organization for a given enterprise and, if possible, to discover some guiding principles or criteria which may be accepted as representative of good organization practice. In this chapter attention will be directed to the more specific problem of organization for production. What, for example, should be the relation of the production department to the organization as a whole? For what activities should the production manager be held responsible? What basis or bases of departmentation should be employed in organizing its activities? What combinations of these activities may be expected to provide the most effective administration of production?

Obviously, categorical answers cannot be given to such questions. The nature and scope of the production department depend not only upon the nature of the enterprise but also upon the managerial talent which is available. The very mention of the production department implies that the basis of departmentation employed, in part at least, in the major departments of the enterprise shall be functional in character; but even with this tacit assumption, there is no assurance that one organization will bear much resemblance to another. The organization within the production department of an automobile manufacturing company is in many respects unlike that employed by a textile plant, a meat-packing establishment, or a flour mill. Indeed, it may not, because of differences in personnel, bear much resemblance to another even in the same line of business. As pointed out in the last chapter, however, these differences are apparent not so much because the activities to be performed differ in kind as because they differ in relative importance. An analysis of the activities associated with production in one industry is not much different from that in another, but the organization charts of the production departments in two industries are almost certain to be different. Our inquiry, therefore, must necessarily

be confined to analyzing production activities and pointing out the peculiar characteristics of these activities which must be considered in any case when assigning responsibility for performance.

Analysis of Production Activities.—All production processes include three essential phases:

a) Preparation
b) Performance
c) Evaluation or measurement[1]

Under the first may be included all activities directly associated with providing the facilities and factors required in manufacturing the product. This involves (1) the *planning* of products, methods, and operations, and (2) the *procuring* of plant facilities, raw materials, and working forces.

Under "performance" may be included all activities which must be performed in conjunction with the actual transformation of the product. This involves not only operations performed directly upon the materials in process but also all manufacturing services, such as power production, plant transportation, and tool maintenance. These latter activities differ from processing activities chiefly in that they cause no direct transformation of the product. Their purpose is to contribute necessary services to the processing departments.

The third phase of the production process, namely, evaluation or measurement, involves many activities which obviously are not confined to the production department alone. In every department some means must be provided whereby the manager can be kept informed concerning progress and may measure the performance of his subordinates. In the production department, the work of inspection is one of the best illustrations of this group of activities.

Other managerial devices which have as their purpose the measuring of performance include such activities as cost accounting and statistical analysis. These are not confined to the production sphere, although possibly it is true that they have been more generally employed for measuring production than elsewhere in the organization. Cost accounting has, for example, long been regarded as being peculiarly the tool of production management. In fact, many production managers

[1] In suggesting this threefold analysis of production activities, the writer wishes to acknowledge his indebtedness to Hamilton Church and Oliver Sheldon. Both of these writers have made distinct contributions to the literature of management by their lucid analyses of managerial activities.

still insist that they, and not the accountants, should have control over cost-accounting activities. In many instances this claim has no doubt been fully justified. There is much truth in the contention of production executives that accountants have failed to appreciate their needs. Too often accountants have been most concerned with keeping records which will enable them to prepare the periodic financial statements. Too often they have lacked the vision and broad experience which would enable them to render valuable service to departmental executives.

This is unfortunate, but it does not appear to be a sufficient reason for insisting that cost accounting should be placed under the production manager rather than the chief accountant. Cost accounting and general-ledger accounting employ the same double-entry technique. Many of the data which the cost accountant employs are derived from the general accounts. The same original evidences and vouchers are the source of information relied upon by both divisions of the accounts. Most important of all, no doubt, is the fact that cost accounting provides a technique which can be utilized by all departments. To insist that it shall be placed under the control of the production manager tends to restrict its sphere of usefulness. The remedy lies in broadening the vision of the accountant, if this is deficient, rather than in depriving him of authority over this important tool of management.

Planning Activities.—By "production-planning," as that term has frequently been used in the literature of production management, is meant the planning, direction, and control of current production operations within the plant. Important as this particular group of activities is, it obviously does not include all planning activities pertaining to production. Rather it is concerned with directing plant operations in accordance with standards, methods, designs, and procedures—all of which are the result of planning—which are supplied by the engineering department.

These latter so-called "engineering activities" may perhaps be said to include industrial research as well as the routine preparation of plans and shop instructions which often is regarded as the major function of the engineering department. It is true that research occupies so important a position in many modern organizations that it is properly regarded as a major activity. Sales, as well as production, have been increased through the efforts of skilled investigators though the research methods employed in the two fields are distinctly different.

Industrial research may be distinguished from commercial research in that it is concerned with the production of goods rather than with their distribution. The former often involves scientific investigation and experimentation with a view to discovering means of utilizing waste or the selection of more suitable raw materials, developing new products, improving processes, or perfecting methods of manufacture. The latter is concerned chiefly with measuring demand, discovering potential markets, and devising more economical means of distribution. Industrial research involves a knowledge of physics, chemistry, and engineering science. Commercial research involves an intimate acquaintance with the principles of economics, with marketing, and with statistical method. Both require somewhat the same attitude of mind but employ entirely different techniques, and need scarcely be placed under the same executive.

On the other hand, a very close relation exists between industrial research and many activities which unquestionably belong within the production manager's sphere. Whether this activity should be placed under the production manager or should be placed in a separate major department under a director of research depends upon its relative importance. In the chemical and electrical industries, for example, where scientific investigation has played a vital part in the growth of organizations, the tendency has been to set up an independent department. In other industries where scientific research is of secondary importance, these activities are sometimes placed under the production manager.

Production standards and specifications are often the media through which the results of research activities are given expression. These are of great variety and, as suggested in a previous chapter, include the following:[1]

a) Standards pertaining to the finished product.

b) Job Standards—including all physical and environmental factors which give character to the job.

c) Standards of performance—involving time and motion study.

All of these are interdependent. At the same time they are, in all cases, so intimately related to production that there seems to be no question but that responsibility for their determination should, with the possible exception of those pertaining to the finished product, be delegated to the production manager.

[1] See chap. xi, p. 187, for a detailed classification of these standards.

Many standards require interpretation if they are to be successfully enforced in the shop. Specifications alone are not sufficient to enable the workman to visualize results, and he must accordingly be supplied with working plans. This is the function of the designing department. The designing process includes two distinct tasks which are clearly differentiated by the different degrees of skill required for performance. The designer must be a man of considerable skill and breadth of training. He must possess analytical ability and imagination in sufficient degree to visualize the thing he seeks to create. He need not be a skilled draftsman, but he must be well versed in the technology of his product and be able to express his views with sufficient clarity to be understood by the draftsman who prepares the record of his conclusions. This is work of a much higher order than that of the draftsman. The latter may possess little creative power and still, by virtue of his technical skill, be able to translate the ideas of the designer into the language understood by the workman in the shop. These different gradations of skill suggest a division of labor between designing and draftsmanship which is frequently observed in the organization of the designing department. Designing activities usually are regarded as being closely akin to production, and for that reason are commonly placed under the jurisdiction of the production manager. In some notable exceptions to this rule, including several automobile-manufacturing organizations, the designing of the product is thought to be of such importance that these activities constitute a major department of the enterprise.

Procuring the Means of Production.—Procuring the means of production comprises an important group of activities in nearly every manufacturing enterprise. This includes the provision of materials, plant facilities, and shop personnel. In the case of materials, storage as well as purchase is almost always involved, since deliveries can seldom be regulated in direct conformity with the daily needs of the processing departments. This is in contrast with the task of procuring a labor supply, though in the latter case procuration involves not merely the activities of the employment department but also all those activities commonly included under the general term of "welfare." Whatever is thought to be necessary or desirable as means of bettering working conditions and promoting personnel efficiency is as much a part of the task of providing a suitable labor force as the work of employment itself.

Apparently there is much difference of opinion as to whether any or all of such activities should be placed under the jurisdiction of the production manager. Many production executives have insisted, for example, that purchasing should be a function of the production department. In justification of this contention it has often been stated that it is of the utmost importance that the production manager shall receive materials which are suitable for his purposes if he is to be held responsible for results. This cannot be denied. Yet it is doubtful whether he need be given authority over so highly specialized an activity as purchasing ordinarily is in an industrial plant. Efficient purchasing requires knowledge of markets and marketing practices which production men seldom possess and often evince little interest in acquiring. It requires an entirely different attitude of mind than that which the production man is accustomed to assume. Furthermore, the interest of the production manager in the purchasing transaction is confined to receiving assurance that materials of the desired quality have been purchased. By giving him authority over material specifications his interests are sufficiently protected.

The purchase of plant facilities and equipment presents a somewhat different situation. It is customary, even where the purchasing department is independent of the production department, to give production executives considerable latitude in procuring this type of goods. Equipment needs are not so readily determined or specified as are raw material needs. It is frequently necessary to make a careful investigation and carry on extended negotiation directly between equipment manufacturers and the production department before the latter can decide what to buy. Purchases of this type are accordingly sometimes made by production executives rather than by the regular purchasing department.

The store-keeping function, in so far as raw materials are concerned, might very well be exercised by the purchasing department, also, were it not for the fact that the production forces must in any case assume responsibility for the custody of considerable portions of the inventory in most industrial plants. All goods in process must be subject to the control of the production manager. Since the problems of material storage and material handling are likely to be much the same before as well as after processing, there appears to be no reason why all stores should not be controlled by the production department.

Concerning personnel activities, practices and opinions differ widely. Formerly, all personnel matters arising out of the relationship of supervisor and worker in the shop would doubtless have been thought to be unquestionably within the province of production. Hiring, firing, training, counseling, and disciplining, all were jealously guarded prerogatives of the old-time foreman. Within recent years, however, the personnel department has emerged. In many quarters it has been felt that the rough-and-ready tactics employed by foremen in dealing with delicate personnel matters left much to be desired in so far as enduring and satisfactory relationships with employees were concerned. The growth of large-scale enterprises in many instances wrought serious havoc with these relationships. The stimulating contacts between employer and employee which we find pleasure in thinking were characteristics of handicraft manufacture, in large measure disappeared with the coming of the factory. Something which gave promise of being an effective substitute was required. It was under such circumstances that the modern personnel department is reputed to have been born. Employment, wage agreements, welfare—all were to be placed in the hands of experts who had the breadth of vision and the skill requisite for securing the best possible utilization of the labor resource.[1]

Whether this new department shall be regarded as being merely another division of the production-manager's activities or shall be accorded the status of a major department is, after all, probably a matter of no great moment. In many manufacturing businesses by far the greatest proportion of employees work in the shops. The personnel problems of other departments are of distinctly minor importance. Under the circumstances it is difficult to see why the personnel manager may not properly report to the manager of production. Well-known instances might readily be cited, however, where the personnel manager occupies the same level of authority as that enjoyed by the head of the production department. Even so vital a task as employment, it has been proved, need not be performed by the department which is responsible for the worker subsequent to employment, provided the latter department is permitted to formulate the specifications for the job and a spirit of co-operation prevails. Co-operation, it may be remarked, is

[1] Doubtless, another potent factor in the development of the personnel department was the organization of labor and the employment of skilled labor representatives. The old-time foreman was no match for these in labor negotiations, and personnel departments were organized in an attempt to regain the bargaining advantage in dealing with employees.

a requisite of success in any organization. It is particularly important in instances such as this, where the adoption of the functional basis of departmentation has led to placing intimately related activities in separate departments.

A Functional Classification of Production Activities.—In the foregoing analysis it has been suggested that all activities more or less intimately associated with the production process need not in practice be included within the boundaries of the production department. The functional basis of departmentation is an exceedingly flexible one. Similarity of purpose, of technique, of training and attitude, or a strong bond of mutual interdependence, may suggest that certain activities should be placed under one authority. But should one of these activities become so highly specialized or of such outstanding importance that it can be administered more expeditiously if placed under separate control, it is but reasonable that this should be done.

In spite of this flexibility, however, there are certain groups of activities which are more or less typical of many production departments. It is for the purpose of indicating a classification of somewhat general application that the following outline is suggested:

A. Engineering activities
  1. Industrial research—scientific investigation and experimentation having as its purpose any or all of the following:
    a) Utilization of waste
    b) Development of new products
    c) Improvement of processes
    d) Discovery of better materials
    e) Improvement of methods
  2. Standardization and specifications concerning the following:
    a) Products
    b) Materials
    c) Equipment
    d) Working conditions
    e) Time and motion standards
    f) Instruction cards
  3. Designing, including creation and preparation of plans and working drawings covering the following:
    a) Plant layout
    b) Equipment and tools
    c) Products

B. Inspection, including the maintaining of all production standards concerning the following:
   1. Buildings and equipment in so far as these affect quality of output
   2. Plant sanitation
   3. Safety
   4. Tools
   5. Raw materials
   6. Goods in process
   7. Finished goods

C. Plant operation
   1. Manufacturing services
      a) Power provision and transmission
      b) Upkeep of buildings and grounds
      c) Equipment maintenance
      d) Internal transportation
      e) Machine preparation and adjustments
      f) Tool storage, repair, and issue
   2. Processing departments—the number and nature of these depending, of course, upon the kind and scope of the operations carried on in the plant

D. Store-keeping
   1. Receiving inbound materials
   2. Raw-material storage and issue
   3. Goods-in-process storage where not undertaken by the processing departments
   4. Finished store-keeping
   5. Packing and shipping where not performed by the sales department

E. Control
   1. Inventory control
      a) Determination of quantity standards where this is performed by the production department
      b) Perpetual-inventory records
   2. Time-keeping and collection of labor evidences
   3. Budgeting
      a) The production budgets
      b) The plant and equipment budget in collaboration with the engineering department
   4. Control of current operations
      a) Routing of work
      b) Scheduling
      c) Dispatching
      d) Collection and preparation of records and reports of progress in the shop

This classification may readily be stated in the form of a chart of activities, as illustrated in Figure 18.[1] Such a chart is suggestive only. There is no intention of contending that it represents the manner in which production activities must be organized. In many organizations some of the activities shown are of such minor importance that they are scarcely recognized in the organization at all. It is well to remember, also, that commodity and territorial, as well as functional, distinctions are often introduced in the internal organization of the production department. Granting this, however, it is still true that within the production department, just as in the organization as a whole, the first division of activities is usually made upon a functional basis. This chart is of interest, therefore, in that it suggests logical functional divisions. The particular combinations of activities included within the various departments, as we shall presently see, conform with the tenets of good organization practice which were suggested in the last chapter.

The Engineering Department.—The engineering department is perhaps subject to more variation in practice than any other subdivision of production activities. An activity which in one industry would unquestionably be regarded as a task for engineers is, in another, regarded as having little relation to engineering. The designing of a steam turbine, for example, is without doubt an engineering problem, and, furthermore, is of such a nature that there is not much question but that it should be performed under the direction of the production manager. The designing of a hat or a pair of shoes—of any style product, in fact—may perhaps be more closely related to marketing than to technology. In many instances it is doubtful whether the production manager should have authority to devise standards, specifications, and designs for the finished product. There can be no doubt in any case concerning the desirability of giving him complete jurisdiction in all these matters in so far as the means of production are concerned. If he is to be held responsible for results, the production manager must be given complete authority over all things which directly determine what these results shall be.

[1] It should be noted that this is a "chart of activities," not an "organization chart." Organization charts have to do with personnel adaptations and must always be influenced by the characteristics of available personnel. Since the personnel factor is always a variable, there cannot properly be said to be such a thing as a "typical" organization chart. There can, on the other hand, be such a thing as a logical and fairly typical grouping of activities in so far as activities may be considered without relation to available personnel.

Many students of organization might possibly object to placing time-and-motion-study work in the same category as the determination

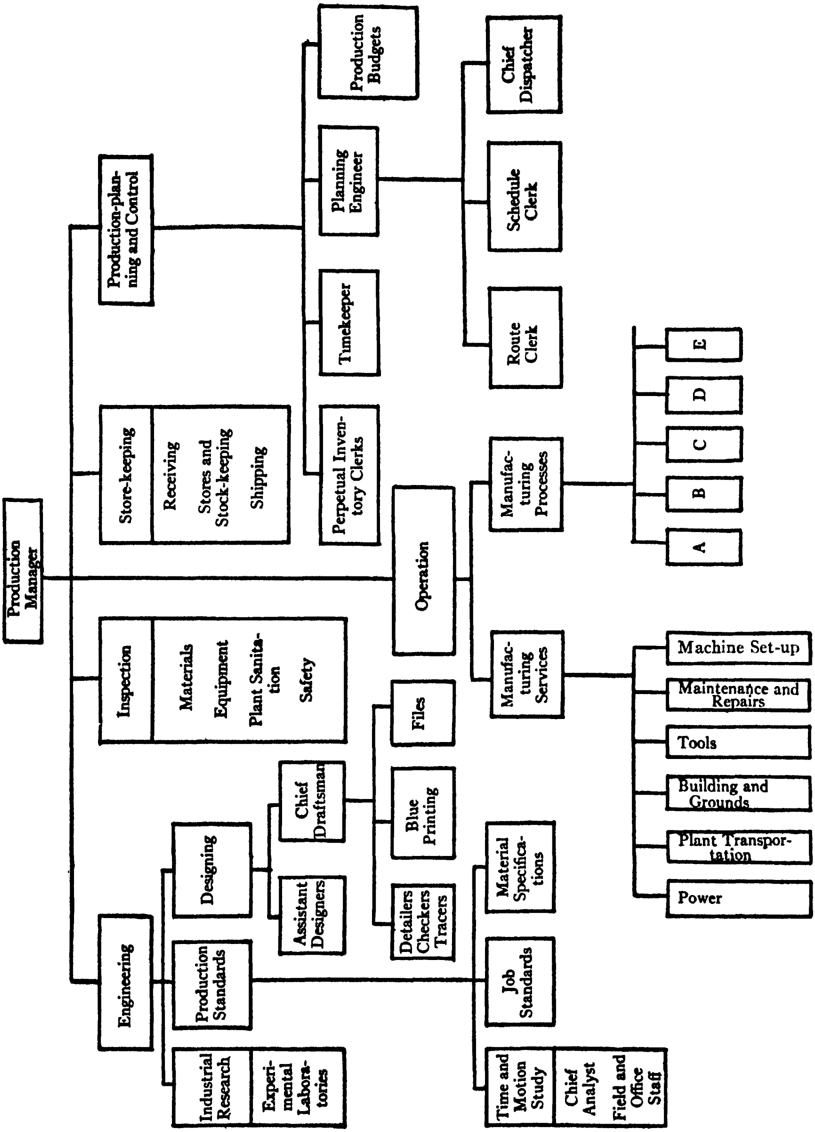


FIG. 18.—Showing a functional chart of activities of the production department

of standards for the finished product, equipment, working conditions, and raw materials. Standards of performance, it might be maintained,

are intimately related to personnel management, and for that reason might better be placed in either the personnel or production-planning departments. There is no doubt but that time and motion study is closely related to personnel. It has its engineering aspects as well. No less an authority than Frederick Taylor repeatedly insisted that there can be no progress in determining standards of accomplishment unless they are considered always in relation to the physical standards of production. It is recognition of this essential unity between all standards which prompts the suggestion that this activity might properly be placed in the engineering department where other standards of production are determined.[1]

Inspection.—All production standards, it has been suggested, are interdependent. Raw-materials standards cannot be formulated without giving consideration to the standards for the finished product. Working conditions and the care of equipment have a direct bearing upon results. Standards of accomplishment cannot be of great value unless these physical factors have been standardized. This interdependence is the chief reason for insisting that responsibility for setting all such standards should be centralized.

But standards must be enforced if they are to be useful. Someone must check results, discover errors, and make suggestions as to how mistakes may be avoided in the future. This is the work of the inspection department. Those who are charged with responsibility for maintaining plant and equipment standards may employ a technique entirely different from that of the inspector of raw materials or of finished products, but the attitude and points of view which must be maintained in both instances are identical. The inspection department must not, in any case, be content with passively checking results. It must be actively engaged in preventing, rather than merely discovering, deficiencies if quality is to be conserved, and should, accordingly, be given a free hand in maintaining all standards.

There would perhaps be little objection in most instances to placing this group of activities under the jurisdiction of the chief engineer also, since no one is likely to be more vitally interested in maintaining standards than the one who is responsible for setting them in the first place.

[1] For an interesting discussion of the place of the time-study department in the factory organization, the reader is referred to the publications of the American Management Association, "Production Executives' Series," No. 75 (1929).

The most serious error to be avoided is the making of the inspection department in any way responsible to the operating forces in the shop. Inspectors are required to pass judgment upon the performance of operating forces and must not be encumbered by embarrassing ties and responsibilities or the quality of production is likely to suffer.[1]

The Operating Department.—Plant operations are of two kinds: The first includes manufacturing services, such as power, plant transportation, tool storage, equipment maintenance, and kindred activities, each of which performs some specialized service for the processing departments. The second group includes the processing departments, themselves, which work directly upon the product.

All such activities are combined in a single administrative unit because of the necessity for close co-ordination rather than because of any inherent similarity in the activities themselves. All are very closely related. Let a service department fail, and the processing departments immediately suffer. All must not only be prepared to render service but to render at the moment that it is required. Teamwork is essential and is likely best to be secured when all are placed under the same authority.

Within the processing division, administrative units must conform with the nature of the enterprise. In some instances, these are determined strictly by functional or processing differences. In others, commodity differences play a large part in determining the nature of these divisions. In many modern plants direct-line production has been emphasized to such a degree that there has been a distinct tendency away from the former common method of grouping machines according to similarity of type. Many commodities are produced in such quantities that it has been possible to organize their manufacture upon a continuous basis, with all machines so arranged that the product passes directly from one to the other throughout the process in a direct line.

[1] G. S. Radford in his very useful work, *The Control of Quality in Manufacturing*, pp. 142–44, does not consider the inspection of buildings and equipment to be within the sphere of the inspection department. It appears, however, that whenever and in so far as the condition of these facilities affects quality of product a strong argument might be presented for including these within the chief inspector's jurisdiction.

This authority would also apparently make the chief inspector directly responsible to the general manager. To the writer this hardly seems necessary, since it undoubtedly is true that no one in the organization is more vitally interested in maintaining quality than the production manager. The inspection department does not pass judgment upon the work of the production manager but upon that of his subordinates.

Different types of machines, such as lathes, boring-mills, planers, and shapers, are not grouped in different departments but are placed in the various commodity processing lines throughout the plant wherever their services are required. This tendency, which has no doubt grown out of the desire to economize plant transportation, has in many instances necessitated a redefinition of the shop foreman's jurisdiction. The authority which he ordinarily must exercise is of such a character that his subordinates must be brought together where all can work under his direct supervision. It is impossible for him to direct all lathe operators only, for example, when these are scattered about the shop in different commodity processing lines. These processing lines themselves, each of which produces a different commodity, become the only practical administrative units. The commodity basis of departmentation is, accordingly, very often employed.

The Store-keeping Department.—One of the requisites for effective inventory control is centralized stores responsibility. This does not mean centralized performance, obviously, since in all large plants it is physically impossible to house all materials in one place. Needless moving of materials about the plant must be avoided; and in consequence, storerooms must be located wherever the efficient operation of material-using departments demands. There is no reason, however, why control may not be centralized. Since the task is identical regardless of whether the materials are unprocessed, partly manufactured, or completely finished goods, all store-keeping may logically be placed under one authority.

In some plants, separate receiving and shipping departments are provided. Where these continue to be placed under the jurisdiction of the production manager there appears to be little necessity for separation from other store-keeping functions. On the other hand, if these are not to be regarded as production activities, the plan is fully justified. Some insist that the receiving of goods, at least, should be a responsibility of the purchasing department. Others have suggested that the traffic department might well assume responsibility for this activity. Both of these departments undoubtedly are interested in knowing that inbound shipments have been received in good condition. It does not necessarily follow that in order to be assured of this fact they must control the receiving and unpacking process.

Outbound shipments are sometimes placed under the jurisdiction of

the sales department. This practice presumably is to be justified on the grounds that the sales department, more than any other, is interested in having the product reach the customer in good condition. In many instances there is some merit in this contention, though it cannot be denied that the packing and loading of many manufactured commodities is similar to many activities of the production department. This latter consideration is the chief reason for placing this activity under the authority of the production manager.

The Production-Control Department.—Production control, or planning, as it is often called, is not always a separate division of the production manager's activities. In some instances many of these activities are of minor importance and are performed by the production manager himself either directly or through staff assistants. The control of current operations, for example, as has been suggested a number of times in this study, involves but slight attention to details where both plant and product have been highly standardized. In many intermittent operations where unstandardized operations necessarily prevail, this division becomes the nerve center of the entire production department. It is the latter, more complex, situation rather than the former which has prompted the analysis of these activities, shown in Figure 18.

Other activities listed under the same department, including inventory control, timekeeping, and budgetary preparation and procedure, are all more or less intimately related with the task of controlling current operations. For that reason it is suggested that they may well be placed under the same authority. They are, without exception, activities which do not strictly pertain to production and, in consequence, are often placed under the functional authority of the controller, though under the line authority of the production department.

Providing for Expansion.—The primary divisions of production activities which have been suggested in the foregoing analysis are in each case functional in character. They represent activities for which control should be centralized, whether the production department is composed of one or a number of manufacturing plants. In fact, in an organization such as described, the results of expansion and multiplication of branches would in all probability be most felt in the operating department. The territorial basis of departmentation would then be employed. A branch manager reporting to the superintendent of operations would be required at each plant. Under him the usual service

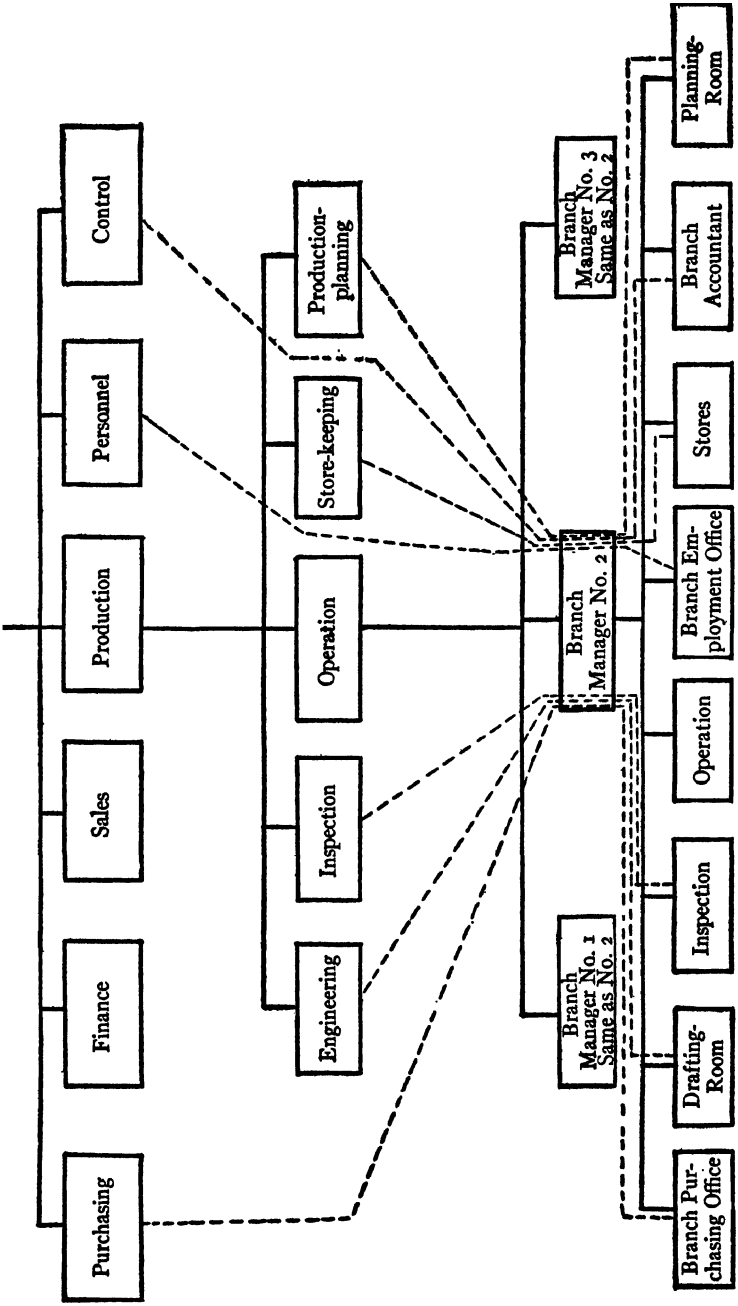


FIG. 19.—Showing functional and line authority as exercised over the activities of a manufacturing branch

and processing departments would naturally be found; and in addition, such of the remaining production activities as pertained to the branch in question would be provided. The latter would logically be placed under the line authority of the local branch manager but under the functional executives in the home office, as shown in Figure 19.

By this device co-ordination would be secured. At the same time expansion, in whatever degree required, could be provided without disrupting the other affairs of the department.

CHAPTER XIV

THE PRODUCTION BUDGET

Dependence of Production upon Sales.—The production department must supply the finished goods which customers are willing to buy. Goods which are of standard design must ordinarily be produced prior to receiving the order, for the purchaser, in such instances, seldom is content to wait long for delivery. Goods which are made according to the customer's specifications cannot, of course, be produced before the order is received, but must, nevertheless, usually be completed as quickly as possible after the purchaser's wants are known. In either case, time is likely to be regarded as an important consideration. The manufacturer who cannot promise delivery within a reasonable time is almost certain to find himself at a disadvantage in comparison with competitors who are able to supply the goods without undue delay.

Co-ordination of manufacturing operations with sales demand thus is one of the most important aspects of production management. It is as an aid in securing such co-ordination that the production budget performs its most important service. If deliveries are to be made promptly, the needs of the sales department must be anticipated and the plans of the production department must be clearly outlined long before orders are received.

The chief difficulties encountered in formulating such plans arise from two sources:

1. Sales demand often fluctuates widely because of extraneous factors and conditions over which the sales department has little control.
2. Production seldom can be undertaken until elaborate preparatory operations have been completed. Equipment must be procured and installed. An organization must be provided and maintained. Neither plant nor organization can readily be adjusted to fluctuations in demand, since the efficiency of both is likely to suffer whenever sudden expansion or contraction of output becomes necessary.

Causes of Demand Fluctuations.—To forecast probable fluctuations in demand for any considerable period in advance often requires consideration of many different factors. In some well-known instances such variations are almost entirely due to well-established habits or customs of consumers. The daily peak-load demand for electric current with which the power-house of a street railway company must contend and the heavy demand at certain hours of the day which a gas company must be prepared to supply are caused by the fact that many customers insist upon doing the same things at the same time each day. Both instances merely reflect the habitual daily routine which life in a highly organized society has forced upon us. The exceptional demand for pianos, radios, and all kinds of holiday goods at the Christmas season is explained by firmly grounded custom which is not likely to be changed merely because it causes irregularity in the demand for such products and in consequence works hardship upon the producer by increasing the risks of manufacture. The pronounced seasonal variation in the demand for wall paper, paints, and varnishes is explained in part by the changing seasons but is augmented by the spring and fall house-cleaning custom.

Sometimes it is climate alone which is responsible for irregularity in demand. The necessity for artificial heat in winter and refrigeration in summer exerts a profound influence upon the demand for coal and ice. The heavy spring demand experienced by manufacturers of awnings and golf clubs, by producers of farm implements and fertilizers, is clearly caused by seasonal changes. The demand for furs in October and straw hats in May is another illustration of the influence of climate upon industry. Both custom and climate tend to cause rhythmical fluctuations. In some industries these movements are experienced with clocklike precision, while in others they are felt little, if at all. To the extent that they are regular in occurrence, the problem of predicting changes is simplified.

Still other fluctuations are caused by variations in the purchasing power of consumers. Lack of funds causes the would-be purchaser to practice self-denial, and thus exerts an influence upon the possibility of making sales. While not predictable with the certainty of seasonal changes, alternating periods of prosperity and depression are sufficiently regular in occurrence to be designated as cyclical in character. A general business depression resulting in restricted purchasing power

naturally is felt first of all in the markets for capital goods and the luxury trades; but if long continued, few, if any, producers entirely escape.

In many industries the product is of such a character that in order to stimulate interest new models must be frequently introduced. For various reasons consumers have become accustomed to demanding style changes, and in many instances these changes have assumed a seasonal character. Thus, in the wearing-apparel trades, spring and fall styles which are not entirely to be explained by different climatic conditions at these two seasons have become a necessity for the manufacturer. In the automobile trade, to cite another example, annual, and in some instances even semi-annual, changes in design have become the rule. The introduction of new styles in such industries stimulates sales; but on the other hand, the fact that the customer has learned to anticipate forthcoming models causes him to defer purchase for a time prior to their appearance, thereby aggravating fluctuations in demand.

Economies of Regularized Production.—It is worth noting that sales fluctuations are nearly always caused by varying conditions upon the demand rather than the supply side, for rarely, if ever, do irregular operations prove to be a boon to the production department. Plant capacity is relatively inelastic. Investments in fixed assets cannot be withdrawn whenever demand declines, nor be reintroduced the moment demand increases. In consequence, the manufacturer who builds a plant which is able to meet requirements during the busy season is faced with the necessity of partially discontinuing operations when requirements decline. Much the same difficulty, though in less degree, is met with respect to the plant's labor resources. Some relief is afforded by irregular employment of workers but always at the cost of lowered efficiency and severe hardship to the working force.

The effects of irregular operations are no doubt more pronounced in the production department than elsewhere in the organization, but are in some measure felt in all departments; and much thought has been given by progressive managers to ways of coping with this evil.

Means of Regularizing Production.—Fortunately, manufacturers are not entirely at the mercy of the whims and temporary necessities of their markets. In many industries it is not impossible to predict with reasonable certainty what the demand for a given product will be for a considerable period in advance. Production may, in consequence, pro-

ceed at a fairly regular rate in spite of the fact that demand fluctuates. In slack periods surplus production is transferred to the stockroom, where it is allowed to accumulate in anticipation of increased sales during the busy season.

The practice of manufacturing for stock is obviously limited to industries which are engaged in producing standardized goods. Its justification, in any case, must depend upon whether the added risks and costs of piling up inventories during the slack season are exceeded by the extra costs which would be incurred by irregular production. In practice, the result is usually a compromise between these two considerations, the rate of production tending to be somewhat restricted in off-seasons and to be increased when sales increase, though not in direct proportion to sales fluctuations.

Another common method of securing greater regularity of employment for men and machines in the plant is by means of diversification and the introduction of complementary products. Often commodities which are demanded at different seasons can be produced in the same plant with the same labor force which is shifted from one to the other as changes in demand occur. The coal and ice business is a stock example of this type, but there are many other instances in industry where plant operations have been regularized through diversification.[1]

Still another method of eliminating costly fluctuations in plant operations is to attempt to regularize the sales curve itself. Often it has been found that, by exerting extra sales effort or by presenting new appeals or special inducements during the slack season, sales can be stimulated with very beneficial results to all concerned.[2]

Sometimes these inducements have taken the form of attractive price reductions during the dull season. Sometimes the desired result has been achieved by exerting more intensive sales effort when customers are reluctant to buy. And sometimes sales volume has been maintained by opening new markets, such as are offered by export trade. Such remedies, if they may be applied, make it unnecessary to produce for stock with the uncertainties and risks incurred by so doing.

Purpose of the Production Budget.—To be successful, any attempt to regularize production must fully recognize two important facts:

[1] See P. M. Atkins, "Solving the Problem of Seasonal Goods," *Administration*, October 1, 1921.

[2] The Dennison Manufacturing Company, producer of paper goods, affords an instance where this method has been applied with very beneficial results.

1. The purpose of regularization is to utilize the resources of the organization, and especially those of the production department, in the most efficient manner possible.
2. Whatever the means employed, the production department must, in the final analysis, be guided by what the sales department is able to sell at a profit.

Both of these statements of fact serve to emphasize the need for a production budget. As already mentioned, manufacturing usually involves elaborate preparations. Raw materials and supplies must be purchased and delivered to the plant. Processing involves the use of both labor and machines and often requires several weeks or even months for completion. Most significant of all, perhaps, is the fact that adequate plant facilities must be provided. Once an investment of this nature has been made, it can only be recovered through operation.

Furthermore, in carrying on these operations considerable financial outlays are necessary. Until production schedules have been formulated, the financial department is not in a position to determine what expenditures will be incurred nor from what sources needed funds can best be secured. The production budget thus serves a twofold purpose:

1. It defines the task of the production department and enables production executives, and others whose function it is to serve this department, to plan the operations required for meeting the manufacturing schedule.
2. It provides an accurate forecast of probable financial needs of these departments, thereby enabling the executives of the financial department to proceed with plans for procuring funds.

Form of the Budget.—While, in general, the production budget in any manufacturing organization should serve both these ends, it must not be forgotten that each company has its own special problems. The methods of preparing the budget and the form in which it is likely to prove most useful must, in each case, be adapted to existing conditions. An organization which manufactures only for special order and carries no inventories obviously has an entirely different problem than one which manufactures for stock. A continuous-process industry, such as a flour mill or a cement plant, has an entirely different set of problems in the preparation and use of its production budget than does an intermittent-process industry, such as a machine tool shop or a furniture

factory. In a flour mill one main product is manufactured. The entire plant is operated as a single unit. There is no such problem as deciding whether to continue to operate one department and close down another; to lay off one group of machine operators and retain another; to adjust the production schedule of product A to that of product B so as to secure greater utilization of machines and men. All such considerations are likely to become real problems in a plant which produces many products on an intermittent basis.

In the remainder of this chapter attention will, for the most part, be directed toward the problem of preparing and using the production budget as it is presented in an intermittent-processing type of plant. This is proposed not because the methods employed in such cases are more generally applicable but because under such conditions detailed information with respect to future operations is more essential and the task of preparing an accurate estimate is more difficult than in a continuous-processing type of plant.

In so far as procedures are described, they are meant to be illustrative and suggestive rather than models to be followed in practice. Each organization must devise procedures and budget forms which fit its own needs. But when the scope, nature, and use of the production budget are understood, it is not usually difficult to make the adaptations in any particular case.

Relation of the Production Budget to the Plans of Other Departments.—The production budget is essentially an "expense budget," and as such is closely related to the plans of the sales department. Sales normally provide the chief source of income from which expenses must be paid and profits must be realized. The object of the operations of all departments of a business is to secure a profit. Executives naturally desire to increase their sales whenever profits can be made. All activities of the business are co-ordinated to accomplish this end. There are occasions, no doubt, when the size of the existing plant must place definite limitations upon the amount of goods which an organization should try to sell, but only when expansion is, in the long run, likely to prove unprofitable. This cannot be decided until future sales possibilities have been estimated.[1]

[1] The dependence of production plans upon sales possibilities is well illustrated in the following quotation describing the budgetary practice of a tool manufacturing company:

"Our first consideration after our sales estimate for the ensuing year is decided upon is to make provision for the execution of this schedule in the factory which invariably means

The budgetary program, therefore, usually originates in the sales department. The effect of the sales estimate upon the plans of every other department is then studied in order to arrive at a properly co-

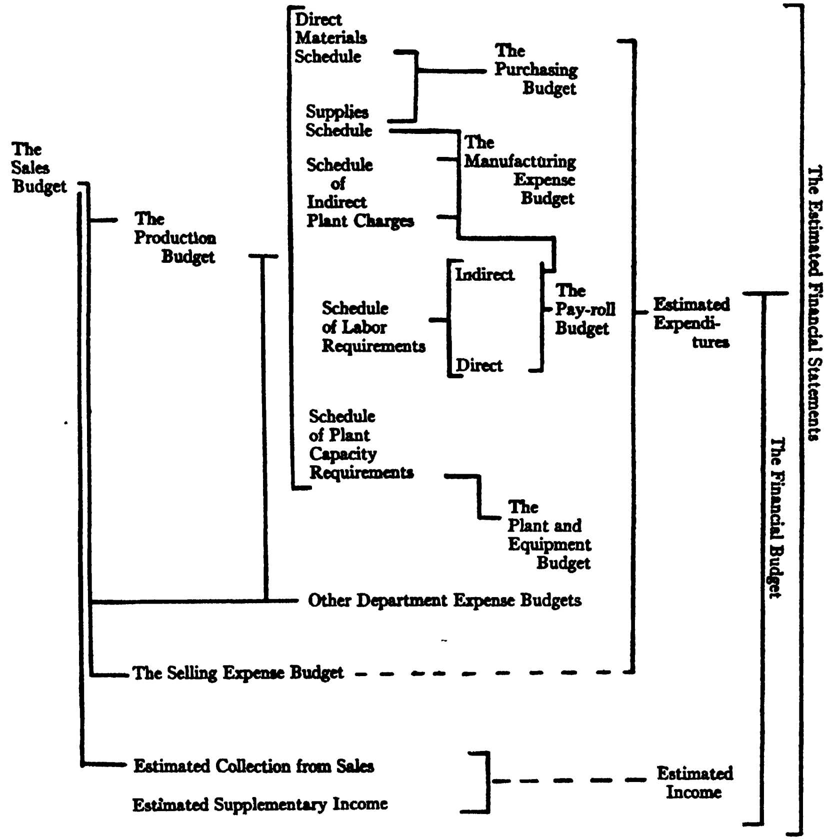


FIG. 20.—Diagram showing the interrelation of the various departmental budgets

ordinated budget for the entire business. This interrelation of departmental plans and the important rôle played by those of the production department in the budgetary program is indicated in Figure 20.

Determination of Production Requirements.—When goods are manu-

additional equipment. . . . . If during the year our sales should exceed our estimate, additional equipment is added to take care of the increase providing we feel it is permanent." (William A. Rowe, production manager, Black and Decker Manufacturing Company, *Publications of the American Management Association, 1927*, "Production Executives Series," No. 62.

factured only after sales orders have been received, the quantities of finished goods included in the production budget will, of course, be identical with those shown in the sales budget. This is not likely to be true, however, when goods are manufactured for stock. Under the latter circumstances the finished-goods inventories in the stockroom act as a buffer between production and sales and must be taken into account when production requirements of a given period are being determined.

Standard turnover rates are often used for determining the size of the inventory which should be carried in proportion to expected sales. The rate of turnover for finished-goods inventories is expressed by the ratio between sales requirements and the average inventory of finished goods carried in stock during a given period as shown by the following equation:

$$T \text{ (turnover)} = \frac{S \text{ (sales, expressed in units)}}{I_a \text{ (average inventory, in units)}}$$

The first step in using this method is to establish standard turnover rates for the various commodities carried in stock. A careful study of past experience usually reveals that this ratio for a given commodity or group of allied commodities remains fairly constant in amount from year to year for the same month, though there may be wide monthly variations within any given year. This is especially true if sales are inclined to be seasonal in character, the ratio tending to increase in amount during months when demand is active and to decline when sales fall off. The experience of preceding years is accordingly analyzed, and standard monthly turnover rates are established for each commodity or group of commodities. These ratios are in turn used for computing the amount of inventory which should be carried in proportion to the estimated sales for the month. This computation involves merely a transposition and substitution of values in the equation given above as follows:[1]

$$I_a \text{ (average inventory to be computed)} = \frac{S \text{ (from sales estimate)}}{T \text{ (standard turnover rate)}}$$

The next step is to determine how much goods must be produced each month to maintain the inventory balances thus established. For this purpose the equation

$$P = S - I_b + I_e$$

[1] In all references to inventory and sales in this connection, it should be understood that these are to be expressed in physical units, not value.

is employed, in which P represents the production requirements for the month under consideration, S represents the expected sales during the month, and I_b and I_e represent the inventory on hand at the beginning and the end of the month, respectively.[1] The values to be assigned to I_b and I_e, respectively, in this equation are, of course, not known. For all practical purposes, however, the average inventory (I_a) computed by the first equation may be assumed to be identical with the inventory at the end of the period under consideration (I_e). The beginning inventory (I_b) will, of course, be assumed to be the same as the average inventory of the preceding period. This is an approximation which may safely be made for short periods (usually not more than one month), such as are ordinarily dealt with in preparing the budget. It will not give exact results, especially for long periods; but since it is intended to be used merely as an "estimating device," the results are likely to be sufficiently accurate for budget-making purposes. The resulting computations constitute the schedule of production requirements for the budget period. Figure 21 illustrates a method of summarizing the information contained in the production schedule.

Analysis of the Production Schedule.—This production schedule, or "finished-goods budget" as it is sometimes called, is nothing more than an estimate of the number of units of each product which must be manufactured during the budget period. It is not sufficiently detailed to be of much aid to either production or financial executives until it has been analyzed and restated in terms of the quantities of raw materials, labor, and plant capacity which will be required.[2] This analysis is necessary, first, because costs of production cannot readily be estimated except in terms of these three elements, and second, because the control and use of materials, labor, and plant within the production department present different problems. Plans for supplying each element as needed must accordingly be considered separately.

[1] The equation above will be recognized as merely one form of the equation which the accountant uses for computing the cost of goods sold as shown in the ordinary statement of profit and loss, i.e., Beginning Inventory *plus* Production (or Purchases) during the Period *minus* Ending Inventory *equals* The Cost of Goods Sold.

[2] The procedure which has been discussed, it should be observed, is applicable only when finished goods are of standard design and are manufactured for stock. It would not apply at all where goods are non-standardized and manufactured for special order. In extreme cases of the latter sort, it may even be impossible to prepare a sales estimate except in terms of "dollars of sales." Production executives, in consequence, can do little more than make approximations as to the amounts of raw materials, labor, and plant capacity which from past experience are likely to be required if the expected sales volume is realized.

The Schedule of Direct Materials.[1]—The direct materials which will be used in carrying out the proposed production schedule may readily be computed with the aid of standard bills of materials. These require-

SUMMARY OF PRODUCTION REQUIREMENTS

For the Budget Period
Beginning January 1st
and Ending July 1st

Commodity	January				February		
	Estimated Quantity Sold	Beginning Inventory	Estimated Quantity Produced	Ending Inventory	Estimated Quantity Sold	Estimated Quantity Produced	Ending Inventory

FIG. 21.—Illustrating a form of production-budget summary

ments may then be summarized in a direct-materials schedule. The purpose of such a summary is twofold:

1. It represents a necessary step in estimating the costs to be incurred by the production department during the budget period, since direct material costs nearly always comprise an important part of total production costs.

[1] The terms "direct" and "indirect," when applied either to materials or labor, are here used in the same sense in which cost accountants ordinarily use them. For example, "direct materials" are those which may readily be identified with a specific product or manufacturing process. Their cost is charged *directly* to the product resulting from their use. "Indirect materials," on the other hand, cannot readily be identified with any specific unit of finished goods. Their cost must accordingly be charged to the finished goods *indirectly*. Such costs are ordinarily charged to a general pool or indirect expense account from which they are in turn allocated to the finished products by means of a pre-conceived "burden distribution rate." Examples of direct materials and labor are the wood and the services of the cabinetmaker used in making a table in a furniture factory. The sandpaper, brooms, and waste used in such a plant and the services of the janitor and truck-driver, afford illustrations, respectively, of indirect materials, or "supplies," and indirect labor.

2. It provides information which is incorporated in the materials budget, as will presently be explained. The latter is used by the purchasing department when preparing the purchasing budget.[1]

The Supply or Indirect Materials Schedule.—Factory supply or indirect-material requirements are determined more by the operating program in each plant department than by the specific orders of finished goods to be manufactured. Plant foremen can, as a rule, exercise little control over the amount of direct materials used in their respective departments, for direct-material requirements depend upon what is being manufactured. They can, however, exercise control over the amount of supplies consumed by their departments, and must be held accountable for waste or inefficiency.

There are two possible procedures by which indirect material requirements may be estimated at the beginning of the budget period. The first is to assign the task to some one upon the staff of the executive in charge of the budgets of the production department. The second is to require each foreman to submit an estimate including all supplies which he thinks his department will require during the budget period. The latter procedure is preferable not only because it compels each foreman carefully to consider the requirements of his department but also because it provides a standard allowance by which his performance may later be compared and which he will feel personally obligated not to exceed.

When this procedure is followed, the executive in charge of the production budget combines the estimates of all departments with the direct-material schedule to form the materials budget which is submitted to the purchasing department. A convenient form of materials-budget summary is shown in Figure 22. The physical quantities only are supplied by the production department. The cost of the materials is estimated by the purchasing department.

The Direct-Labor Estimate.—Labor and plant capacity requirements usually can be determined only by making a careful analysis of the methods of manufacture employed in the production of each commodity included in the production schedule. An accurate knowledge of labor-hours and machine-hours involved in each operation is required

[1] For a discussion of the problems involved in preparing the purchasing budget, the reader is referred to the author's *Purchasing* (Ronald Press), chap. xviii.

for making the necessary computations. When the product is of standard design and is similar to that which has been manufactured in past periods, this information is obtainable from the records of the production-planning department. Even when no such records are available, the task of predicting the labor requirements involved in the manufacture of an article is no different than this department must always assume in routing and scheduling the order prior to undertaking its production in the shop.

THE MATERIALS BUDGET

For the Period
Beginning January 1st
and Ending July 1st

Commodity	January		February		
	Quantity Required	Estimated Cost	Quantity Required	Estimated Cost	

FIG. 22.—Illustrating a form of materials budget

When direct-labor requirements have been computed, they are classified as to type of labor required and are summarized as shown in Figure 23. The purposes of this summary are as follows:

1. This estimate, in conjunction with the estimated indirect-labor requirements, provides the data which are needed for preparing the pay-roll budget. The latter, which is based on the labor estimates of the production department, is often prepared by the personnel department and represents the estimated expenditures for factory wages to be incurred during the budget period.

2. The labor estimate provides the personnel department with information required in estimating the welfare-expense appropriations for the budget period.
3. It provides the production-planning department with a summary view of probable labor requirements during the entire budget period, thereby enabling it to schedule current production in the manner best designed to utilize the labor force in an efficient manner.

THE LABOR BUDGET

For the Period
Beginning January 1st
and Ending July 1st

Grade of Labor Required	January			February	
	Estimated Total Labor-Hours	Estimated Overtime	Estimated Cost	Estimated Total Labor-Hours	

FIG. 23.—Illustrating a form of labor budget

Indirect-Labor Requirements.—Indirect labor, unlike direct labor, seldom varies in direct proportion to the volume of production, and is therefore often somewhat more difficult to estimate in advance. It consists, for the most part, of the labor required by manufacturing service departments, including the power department, the buildings and grounds department, plant transportation service, stores department, and the departmental clerical forces, which in many instances cannot be reduced below a certain minimum even when many of the processing or direct-labor-using departments are practically idle. No procedure can be devised which is generally applicable to the problem as presented

in such widely differing circumstances. The head of each department must be held responsible for a reasonable estimate of his indirect-labor requirements. By so doing, departmental foremen are given a sense of personal responsibility for the indirect-labor costs of their departments. An incentive to prevent waste and inefficiency is thereby provided.

Indirect-labor requirements may be summarized in a form similar to that used in connection with direct labor as shown in Figure 23 previously mentioned.

The Plant-Capacity Requirement Schedule.—Plant-capacity requirements may be expressed in terms of machine-hours, production-center-hours, or department-hours, depending on the nature of the manufacturing processes employed.[1] Figure 24 illustrates a form which may be used in summarizing this estimate. Such a schedule is of use:

1. As a basis for estimating manufacturing expenses.
2. As a basis fo· determining additional requirements for plant and equipment and preparing the plant and equipment budget.
3. As a working guide for the scheduling section of the production-planning department in scheduling current production orders.

The Manufacturing-Expense Budget.—Cost accountants ordinarily divide production costs into three groups: (*a*) direct materials, (*b*) direct labor, and (*c*) manufacturing expense. The latter division includes all those costs which cannot economically be charged *directly* to the product, and is in turn composed principally of (*a*) indirect material charges, (*b*) indirect labor charges, and (*c*) so-called "fixed charges," including such portions of current or past expenditures as are allocated to the period's operations in the form of depreciation, obsolescence, rent, insurance, and royalties, as well as allowances for the use of invested capital, provided it is the policy of the organization to include interest on plant investments in the cost of production.

[1] "Production-center" is a concept often employed by cost accountants. It may consist of a single machine or unit of equipment such as a work bench, with its necessary auxiliary equipment and allotment of floor space, or may include a series of machines which are always operated as a unit in a given sequence. Cost accountants sometimes use the production-center as a means of identifying indirect expenses or "overhead" with the product. Expenses are first allocated to production-centers and production-center-hour rates are computed. The finished product is then charged according to this rate for the number of hours it remained in process in the production-center.

The use of the production-center or department as an estimating unit for either costing or budget-making purposes obviously is limited to those instances where all the machines or equipment in the production-center or department are used as a single unit in the manufacture of the product.

In preparing a budget of the costs of operating the production department, it is desirable that the cost accountant's classification should be observed not only because it provides the most natural and convenient classification for compiling an estimate of costs but also because the estimates should be capable of being compared with actual results compiled by the cost department. Such comparisons are essential if the budget is to be of much value as a control device.

SCHEDULE OF MACHINE REQUIREMENTS

For the Budget Period
Beginning January 1st
and Ending July 1st

(1) Machine No.	January				February	
	(2) Estimated Machine-Hours Required	(3) Present Capacity in Machine-Hours	(4) Excess Capacity Available	(5) Additional Capacity Required	(2) Estimated Machine-Hours Required	

FIG. 24.—Illustrating a Machine-Requirement Schedule

No special difficulties are encountered in preparing the manufacturing-expense budget. Indirect material and labor charges which comprise a large proportion of such expenses in most manufacturing plants can best be estimated by the foremen of each department, as already discussed. The remaining components of indirect expense, with but few exceptions, represent an allocation of charges previously entered in the accounting records. These exceptions, including such items as rent and insurance, are easily estimated in advance.

Co-ordination of the Production Budget and Plant Capacity.—One of the most valuable contributions made by the schedule of plant requirements is the light it throws upon the probable needs for additional

equipment in the plant. In Figure 24 this is clearly indicated in column 2 which shows the number of hours of operation which will be required of each type of equipment in the plant. In column 3 is shown the present capacity of each type of machine; while in columns 4 and 5 are shown the surplus capacity or the additional capacity required, as the case may be. This enables production executives to judge the desirability of the proposed program.

Should the fulfilment of the program in any case require machine capacity in excess of that already available, obviously some adjustments must be made or the production schedule cannot be maintained. In such instances three possible solutions are presented:

1. The production schedule may be revised downward in sufficient amount to avoid the necessity of procuring additional equipment. The desirability of this course will in large measure depend upon whether the expanded schedule which is contemplated can be maintained upon a profitable basis in future periods. If it is to be only temporary, the purchase of additional equipment may mean excess capacity and idle equipment in future periods when the temporary increase in demand has ceased.
2. A careful study of the operations involved in producing the excess product may be made with a view to determining whether part of the operations cannot be shifted to other machines in the plant which, according to the schedule, may not be fully occupied during the budget period. Often it is preferable to use a substitute machine for performing some operation even though it may perform it less efficiently than the machine upon which the work was originally scheduled rather than to allow the less efficient machine to stand idle.
3. Additional equipment may be procured to care for the increased demand. This is, of course, entirely justifiable if the increase is expected to be permanent or sufficiently profitable to provide for reasonable amortization of the purchase price of the equipment. Such expenditures comprise the basis for the plant and equipment budget which was discussed in chapter vii.

Responsibility for Preparing and Enforcing the Budget.—The utility of a departmental budget depends in large measure upon (*a*) the extent to which it represents a workable and a desirable program, (*b*) the extent to which it represents the best thought of executives with respect to

what they hope to accomplish, and (*c*) the extent to which it is actually regarded as something to be achieved or exceeded in practice. How nearly the budget will come to meeting these general specifications will depend upon the plan of organization devised for preparing and enforcing it. The preparation of the production budget is an arduous task at best; and if it is to mean anything, it cannot be attacked half-heartedly. It is axiomatic that the responsibility for preparing a departmental budget should be placed upon those who will have to assume the burden of putting its provisions into effect. This latter responsibility in the production department is placed squarely upon the production-planning department. It is entirely logical, therefore, to provide a division within that department to which may be assigned responsibility for all matters pertaining to the preparation of the budget.[1]

The exceptions to this rule which seem desirable are the estimates pertaining to indirect labor and materials. If these components of production cost are to be effectively controlled, each foreman within the production department must be held responsible for the expenditures of this nature which are incurred under his supervision.

The enforcing of the program primarily consists of seeing that the appropriations assigned to the various departments are not exceeded without good reason. This involves a comparison of results as presented in the reports of the cost department with the budget estimates. The making of such comparisons is a responsibility which the production manager himself must assume for his department.

[1] This conclusion presupposes the existence of a central planning department, which is not always the case, particularly in plants where continuous processes predominate. Even in the latter type of plant, however, someone must perform the planning function, and the budgetary executive might conceivably report directly to the production manager.

CHAPTER XV

PRODUCTION-CONTROL PROCEDURES

The Control of Production.—The separation of planning and performance which Frederick Taylor advocated has become a well-established fact in the modern production department. The soundness of this principle is today accepted without question, though the administrative details by which it was hoped to accomplish this result have necessarily been adapted to present conditions. In many organizations much of the responsibility for planning and directing shop operations has been delegated to a production-planning department, and elaborate procedures governing this department's performance have been found useful. It is proposed in this chapter to analyze this functional department in detail and outline procedures by which control ordinarily is exercised.

The planning of production operations involves four considerations: (1) *what* to manufacture, (2) *how* manufacturing operations shall be performed, (3) *where* and *in what sequence* work shall be done, and (4) *when* each operation shall be begun and completed. The latter two, having to do with the order of work and the timing of operations, are ordinarily regarded as the major functions of the production-planning department. They will be our chief concern in this chapter.

What shall be manufactured is, of course, not strictly a production problem. The needs of the sales department and the policies of the general management usually determine, in general outline at least, the answer to this question. The details of product design, which comprise merely another aspect of this general consideration, are the responsibility of the designing department. In practice, as has been previously mentioned, the designing of products may or may not be a responsibility of the production manager. In any case the one who performs this task must work in close co-operation with the production department. All four of these questions are interrelated. One follows the other in natural order, and a spirit of mutual helpfulness must necessarily exist among all interested departments if production is to proceed in orderly fashion.

The second question deals directly with manufacturing methods which, it is generally conceded, are of vital concern. Whether or not

there is, as is often contended, one best method of performing a given task, it undoubtedly is true that some methods are better than others. The foreman, amid his multiplicity of duties, often is not able to determine how a given task should be performed. He should not be expected to assume this responsibility. It is a task for a specialist. Accordingly, under modern conditions specialists prepare detailed specifications as to how each operation should be performed for the guidance of the workman in the shop. The preparation of operating instructions, obviously, is very closely related both to the designing process and to the work of time and motion study. Since both of the latter activities may properly be regarded as functions of the engineering department, it is but logical that responsibility for the preparation of standard shop instructions should also be delegated to this department.

In suggesting that this task is an engineering function, the writer is fully aware that such an assignment of responsibility does not conform with the practice in many organizations. Taylor's scheme of functional foremanship, which undoubtedly was the forerunner of the modern production-planning department, linked together the instruction-card clerk and the route or order-of-work clerk. In many organizations the determination of *how*, as well as *where*, the work shall be done is still regarded as a function of the production-planning department. No one need quarrel with this practice, especially in organizations which specialize in made-to-order unstandardized products. Under such circumstances each order is virtually a law unto itself. Special routing and special shop instructions must be prepared for each operation. The specifying of where and how the work shall be performed becomes an extremely important task, which, under the circumstances, can scarcely be placed under separate authorities.

As a matter of fact, however, relatively few modern organizations specialize in the manufacture of wholly unstandardized products. Even in the intermittent-process industry manufacture is usually repetitive in character. Nearly every production order calls for a product which has been made before or which will probably be made again. When manufacturing instructions and the order of work for a given job have once been prepared, they become a matter of record which may be consulted whenever the order is repeated. Repetitive manufacture, which very likely is more common now than in Taylor's day, has thus greatly simplified the tasks of routing and shop instruction. Standard routings for each product may be prepared. Shop operations can be anticipated,

and standard instructions for each operation are written in advance and filed for future reference. The route clerk's task, consequently, is standardized and simplified to such a degree that the routing of a production order entails little more than preparing and assembling standard route sheets, instruction cards, and work orders, authorizing operating forces to proceed with the job.

Wherever continuous-processing manufacture has supplanted intermittent operations, as has frequently been the case, the control of production has been still further simplified. Operations become altogether repetitive. How each operation shall be performed becomes a matter of established routine. Where work shall be done and operating sequences are determined when each processing line is laid out, and in some instances even when the plant is built, the matter of timing operations becomes less intricate. Each processing line is ordinarily devoted to the manufacture of a single product. There is no occasion for determining what orders shall be given preference in the processing line, which often is the chief task of the scheduling clerk in the intermittent-process industry. Fewer orders need be issued. Those which are essential are standing orders which specify the rate at which production shall proceed and remain in effect until a change in this rate is desired.

Under such circumstances, a specialized production-planning department is not required. The infrequent standing orders necessary to insure orderly operation in the shop may be, and usually are, issued directly from the production manager's office.

In the discussion of the functions of the production-planning department in the remainder of this chapter, it must be borne in mind that we are considering the problem of production control as it is presented in an intermittent-process industry. Control of production in the continuous-process type of industry is so simple that it requires little consideration. Many industries fall somewhere between two extremes. They are neither of the unstandardized non-repetitive order type in which the control of production is highly complex nor are they of the continuous type where a specialized production-planning department would be superfluous. Products are standardized but are sent through the plant in lots.[1] These lots do not move automatically from process to process in a continuous sequence, and hence close supervision must be

[1] D. S. Kimball (*Principles of Industrial Organization*, p. 137) suggests this distinction in intermittent-process types, which he designates as (1) lot intermittent and (2) special-order intermittent.

exercised. Control procedures need not be as complex as when processes are completely unstandardized but well-organized scheduling and dispatching facilities are still essential. Like all other devices of production management, control procedures must be adapted to the organization in which they are to be installed. When the theory of production planning is understood, it is not difficult to make whatever adaptations are necessary.

Functions of the Production-planning Department.—The production-planning department performs three important functions:

1. *Routing:* The determination of the order of work and the preparation and assembly of the route file for each job. This file consists of all work orders, requisitions, instructions, and labor tickets which will be required in routing the job through the shops.

2. *Scheduling:* The timing of all operations with a view to insuring their completion when required, and at the same time making the best possible utilization of existing plant facilities.

3. *Dispatching:* The issuing of all shop orders as required in complying with the wishes and instructions of the routing and scheduling divisions of the department.

To these should be added a fourth function, namely, the collection and organization of information with respect to the progress of all work orders in the shop. This function is often performed by the dispatchers, who at stated intervals prepare progress reports for the information of the scheduling division.

The Production Order.—Shop operations are initiated by means of production orders. For special orders involving products not customarily carried in stock, such an order originates in the sales department and is transmitted to the production manager. If designs and working drawings are required, as is often the case when the product is made to order, the designing department is instructed to prepare these, including special manufacturing instructions if required, detailed bills of materials, and specifications. When these have been supplied, they, accompanied by the production order, are sent by the production manager to the planning department. In the planning department, all such orders are classified and broken up into manufacturing lots, and a manufacturing order stating the required date of completion is prepared for each lot. The manufacturing orders and supporting data are then passed to the route clerk for placing in line for manufacture.

The originating procedure is somewhat different when goods are manufactured for stock. In such cases, standard working drawings, bills of material, and operating instructions are, of course, already available, and the originating office is not the sales department, but the perpetual-inventory stock-ledger clerk. The latter prepares a production requisition whenever the supply of any product must be replenished and transmits this to the production-planning executive,

Part No. *R279* ROUTE SHEET Lot No. *M4602*
P. O. No. *40731* No. in Lot *100*
Drawing No. *32966* Date

Oper. No.	Description	Std. Time	Total Time	Machine	Mach. Rate	Alt. Mach.	Mach. Rate	Remarks
1	*Forge blank*	*0.08*	*8.00*	*F71*	*2.40*	*F64*	*3.10*	*Prep. time, 1½ hrs.*
2	*Machine face*	*0.12*	*12.00*	*M316*	*3.75*			
3	*Drill*	*0.05*	*5.00*	*D22*	*1.60*	*D36*	*2.20*	*Prep. time, ¾ hr.*
4	*Heat treatment*		*6.00*					
5	*Rivet lug*	*0.045*	*4.50*	*P37*				*Prep. time, 1½ hrs.*
	To process stores							
6	*Grind and polish*	*0.116*	*11.60*	*R310*	*0.85*	*Q416*	*1.45*	
7	*Inspect*		*3.75*					
	To w. m. stores							

FIG. 25.—Illustrating a form of route sheet employed by a production-planning department.

who, provided he approves, prepares a manufacturing order authorizing the route clerk to proceed with production as in the previous case.

Routing the Work.—The routing function consists of analyzing manufacturing orders and preparing a route file for each manufacturing operation. Manufacturing orders seldom include more than one product, but in the case of assembly products ordinarily require the manufacture of several different parts or product components. These components must, of course, be given individual treatment in the shop. The first task of the route clerk, therefore, is to prepare a route sheet for each

product component. This consists of a list of all operations, arranged in proper sequence, which must be performed in the manufacture of the part. The type of machine to be used with possible alternate machines, if there are such, and the standard times allowed for each operation are also shown, as illustrated in Figure 25.

The route sheet is an important document since it provides the master control governing all subsequent planning processes associated with the manufacture of the product. The information shown thereon enables the scheduling clerk to prepare his manufacturing schedules. In the manufacture of standard parts such route sheets are, of course, ordinarily prepared in standard form in advance, but for special order work an original analysis must be made. Where this latter task must frequently be performed by the route clerk, it is obvious that he must be well versed in the technology of his industry.

An order file is next prepared to accompany the route sheet. This file includes all orders and written instructions which will be required for controlling operations while the goods are in process. The number and character of orders required depends upon local conditions. In a highly organized shop all of the following are sometimes employed:

1. *Work orders*—one for each operation appearing on the route sheet. These constitute the authority for the shop foreman to proceed with the work.

2. *Time cards*—one for each workman assigned to the job. These eventually become the labor evidences from which the pay-roll and cost records are compiled.

3. *Shop instructions*—including instruction cards and shop drawings as required.

4. *Material requisitions*—authorizing the issue of materials from stores as required.

5. *Service orders*, including inspection orders, move orders, tool requisitions, and machine set-up orders to be issued to the manufacturing service departments as required.

The assembling of the route file marks the completion of the route clerk's task. The file is then sent to the scheduling division, which is responsible for the timing of operations.

The planning process as thus far described is illustrated in graphical form in Figure 26.

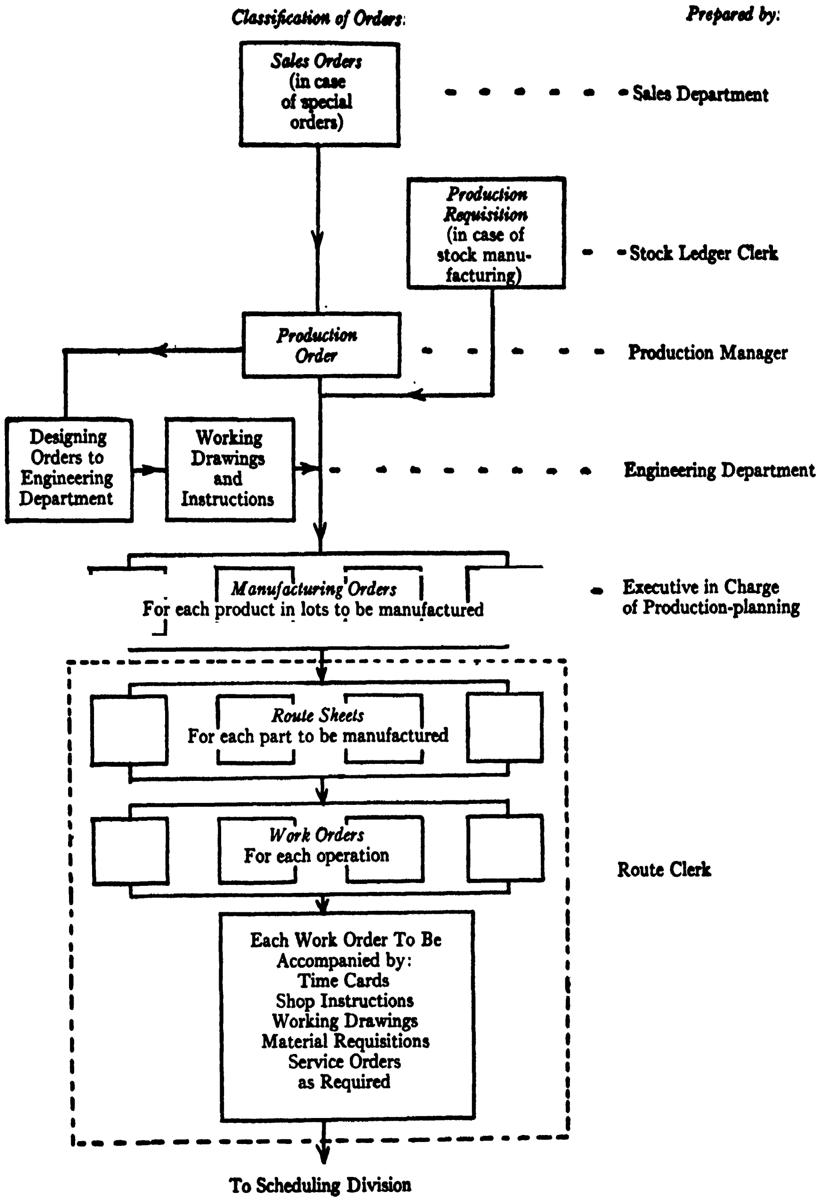


FIG. 26.—Chart showing a classification of the various kinds of production orders employed in controlling production in an intermittent type of industry.

Scheduling the Work.—It is the function of the scheduling division to determine when each operation should be begun in the shop. In performing this task, two important considerations must always be kept in mind. First, each manufacturing order must ordinarily be completed within a given time. Second, there is always the efficiency of the plant to be considered. Operations must be timed in such a fashion that idle machine time will be reduced to a minimum. In the intermittent-process type of plant many machines are employed on many different orders, and much depends upon the scheduling clerk. He must strive to maintain a smooth flow of production through the plant. Sometimes this entails the deferring of orders for which the time of completion is not important. In other instances, work must be diverted to alternate machines when points of congestion develop in the shop.

Many ingenious devices, such as graphical load charts and progress diagrams, have been designed for the purpose of aiding him in performing this difficult task. Some of the more serviceable of these will be described and illustrated later in this chapter.

Dispatching Orders.—The work of the dispatching division begins where that of the scheduling clerk ends. It is the function of this division to keep its finger upon the pulse of the processing departments, to issue the orders of the routing and scheduling divisions as required, to note progress, and immediately inform the scheduling division whenever conditions arise which may require the revision of current production schedules. It maintains the *liaison* between the production-planning department and the shop. Upon its efforts the practicability of separating planning from performance largely depends.

Because of its need for a sympathetic understanding of the problems of the shop, the dispatching department is, in large organizations, often decentralized. The head of the division maintains a central office and exercises general supervision over assistant dispatchers, who spend most of their time in the shop departments. In this manner, each departmental dispatcher is able to maintain intimate contact with his section of the work. He works in close co-operation with foremen, becomes acquainted with men in the shop, and thus is able to dispel much of the distrust which shop men naturally feel towards office employees.

Material-Requisition Procedures.—One of the most important factors in preventing shop delays is the provision of materials when required. Material requisitions serve a twofold purpose: first, they authorize the

stores department to issue materials to the shops; and second, when evaluated, they become the evidence from which direct-material charges are made in the cost records.

Requisitions ordinarily are prepared by the route clerk, who derives his information concerning what is required from standard bills of material which accompany the working drawings supplied by the designing department. Where materials are purchased in anticipation of need, as is ordinarily the case in the modern organization, the practice is frequently followed of detaching material requisitions from the remainder of the route file prior to sending the latter to the scheduling division. These requisitions are sent to the balance-of-stores clerk, who is thus given advance notice concerning materials which will be required within the near future. If these are available, he appropriates the quantities required for the job, and makes a notation to that effect upon the face of each requisition. He then sends the requisitions to the scheduling division, where they are reattached to the corresponding route file. If the materials are not on hand, the balance-of-stores clerk immediately issues a purchase requisition for the required amount, and enters the probable date of delivery upon the requisition. This information is of service to the scheduling division in preparing its schedule for the work.

Nothing further need be done until the work is to be put in process, at which time the dispatcher sends the requisition to the stores department. The storekeeper fills the requisition, makes a notation to that effect upon the face of the order, and returns it to the dispatcher. The latter in turn returns the requisition to the balance-of-stores clerk, who is thereby authorized to make proper entries in his records, indicating that the materials have been sent to the shop. The value of the materials is then entered on the requisition, which is finally sent to the cost department for entry in cost records, thereby closing the transaction.

Recording Labor Time.—There are two general methods of collecting the evidences from which factory pay-rolls and labor-cost records are prepared. In many plants the foreman, or a timekeeper working in close co-operation with the foreman, keeps a record of all labor expended in each department. Ordinarily this record is used, first, as the basis of a time-distribution summary from which the cost department derives its direct labor charges, and second, as a means of verifying the accuracy of the "in-and-out" or "clock" record from which the factory pay-

rolls are prepared.[1] This method possesses the advantage of simplicity, is inexpensive, and well adapted to the needs of a small shop or where workmen are not frequently transferred from one job to another. It is the method commonly employed in continuous-process industries where each man ordinarily is permanently assigned to one job and where the distribution of time for cost purposes is in consequence a very simple matter.

In large intermittent-process departments, and especially where workmen typically are shifted from job to job at frequent intervals, this method becomes cumbersome and may lead to gross inaccuracies in making the distribution of time for cost purposes.

This brings us to consideration of the second method, which is not so much subject to this defect and is perhaps an outgrowth of the same conditions which have fostered the development of the centralized planning department. Time tickets with proper identifications are prepared for each task and are included in the route file when the job is being planned. These are delivered by the dispatcher to the workmen assigned to the job when work is begun. The time of beginning and the time of completion is noted on the ticket, often by means of a time-recording stamp.[2] After receiving the foreman's approval, it is returned to the dispatcher as evidence that the job has been satisfactorily completed. The completed time tickets, having served their purpose as a production-control device, are next sent to the timekeeping department, where they are evaluated, sorted, and summarized, thus serving as the accounting evidences from which the pay-roll and cost records are prepared.

Responsibility of the Shop Foreman.—The development of a specialized planning department has, of course, exerted a profound influence upon the function of the foreman in the shop. Whereas he formerly was compelled to shoulder the major responsibility for planning, as well as execution, of the work assigned to his department, his energies under

[1] Since "in-and-out" or "clock" records are essentially records of time spent, they can be used as the basis for preparation of the pay-roll only when workmen are paid an hourly rate. When piece rates are employed, the pay-roll department must ordinarily rely upon the foreman's record. In the latter case, the chief value of an "in-and-out" record is its disciplinary effect.

[2] Where piece rates are employed, the information required for evaluating the job must, of course, be included on the time ticket.

these new conditions may be confined chiefly to this latter phase of the task. The discretion allowed him in the matter of choice of machines and assignment of workers to given tasks varies in different organizations. It depends largely upon the definition of the duties of the scheduling and dispatching divisions. In some instances these planning divisions assume full responsibility and issue orders and work assignments for each man and machine, in which case the foreman is responsible merely for seeing that these assignments are executed according to instructions. In other instances, the orders of the planning department are less detailed. The type of machine to be used is specified, but decisions as to which machine of this type and which workman shall be assigned to the job are left to the discretion of the foreman.

The second plan undoubtedly allows for greater flexibility in operation, but tends, it is sometimes objected, to breed favoritism in the shop. Some tasks are less difficult than others. In every shop, especially where piece rates are employed, there are likely to be some "soft" jobs which a foreman, if he desires, may contrive to assign to his favorites. The planning department, in contrast, occupies a more detached position, and accordingly may be expected to be entirely impersonal in its assignments. On the other hand, this personal acquaintance with his men which the foreman possesses may be a distinct advantage. An impartial foreman knows the peculiar qualifications and weaknesses of each of his men and may often utilize this knowledge to good advantage in making assignments. In any case, if this prerogative is to be denied the foreman, the planning department must place itself in a position where it, too, may become acquainted with these personal factors which mean so much in maintaining the efficiency of the shop. This personal contact is sometimes secured by decentralizing the dispatching force, as has already been described.

Co-ordination of Planning and Performance.—One of the most serious difficulties with which a planning department must contend is the tendency for performance to lag behind what was anticipated. There are so many things which may cause the breakdown of the schedule. The delivery of materials may be delayed. Machines may fail. Workmen may be absent. Shop conditions may fall below the desired standards and thus retard the work. These delays affect not only the job in process when they occur. All subsequent jobs on the boards are deferred;

and if the condition is not soon rectified, schedules must be rearranged. Some means must be provided whereby the scheduling division may be kept informed concerning progress in the shop.

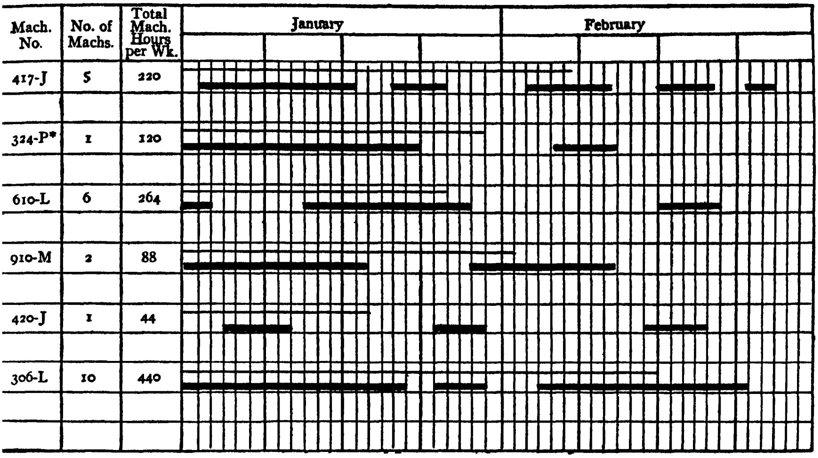
The dispatching division usually maintains this contact. It is the duty of this division to transmit orders to those responsible for performance and to note progress in the shop. This latter task is facilitated by the simple expedient of insisting that all orders shall be returned to the dispatching division as soon as the instructions shown thereon have been carried out. Thus, in the large dispatching office the work is characterized, on the one hand, by a constant stream of outbound orders to the operating forces, and, on the other, by a returning stream of completed orders from these forces, acknowledging receipt and supplying information concerning performance. This system, when supplemented by information gained by departmental dispatchers through personal contact, keeps the planning department informed as to how the work is progressing. This information is summarized, and a progress report is periodically prepared and sent to the scheduling division. The report of progress, which ordinarily is prepared each day, is used for checking the schedule and making revisions as required. It is the chief reliance of the scheduling division in securing co-ordination between planning and performance.

Visual Aids of the Planning Department.—It is obvious that those who are intrusted with scheduling and dispatching, as these tasks have been somewhat briefly described in the foregoing pages, must at all times maintain an intimate grasp of details. Upon their shoulders rests much of the responsibility for the success of the system. Failure of the production department to function is usually in some measure caused by errors in planning. Sooner or later such failures are almost certain to be traced to the scheduling or dispatching forces.

Much thought has been expended upon devices and visual aids which are designed to render this responsibility less burdensome. The literature of production control is replete with descriptions of ingenious charts, and so-called "planning boards" having this as their purpose. No attempt will be made in this brief discussion of control procedures to repeat these descriptions.

Such devices, important as they are in practice, represent merely the form, not the substance, of production-planning. When the function of the production-planning department is understood, such aids can usually be contrived without great difficulty. Many of these devices

are elaborations or adaptations of what is known as the "Gantt Chart." Two such adaptations which required little explanation, a load chart and a graphical progress report, are illustrated in Figures 27 and 28. For excellent discussions of the application of these and kindred devices the reader is referred to more specialized works on this phase of production management.[1]



* Automatic machine operated three shifts or twenty hours per day.

FIG. 27.—Illustrating a form of Gantt Load Chart as used in scheduling production orders. Explanation of chart: Each line is reserved for the schedule on a single type of machine. The heavy line in each case indicates the schedule on the corresponding machine. The light line indicates the total load scheduled on the machine to date.

Illustration of Dispatching Procedures.—Figure 26, previously referred to, illustrates the procedure involved in initiating and routing a production order. The route file prepared in connection with this procedure is passed to the scheduling division as shown, and from there to the dispatching office, where orders are held until the time arrives for issuing them to the operating departments. The disposition made of these orders at time of issue and their final destinations are illustrated in Figure 29.

This procedure, it may be stated again, is not to be regarded as typical of industry in general, nor even of very wide application. It illustrates desirable practice only in industries where highly compicated intermittent processes are employed. In many instances, such a pro-

[1] *The Gantt-Chart*, by Wallace Clark, and *Graphic Production Control*, by C. E. Knoeppel, are especially helpful in this respect.

cedure obviously would be unnecessarily complicated and cumbersome. Since there is no virtue in complexity where complexity is not required, simplification and elimination of unnecessary orders would be necessary to adapt this procedure to the conditions found in most industrial plants. Common sense and a keen appreciation of the desirability of simplicity, when simplicity will suffice, are necessary qualifica-

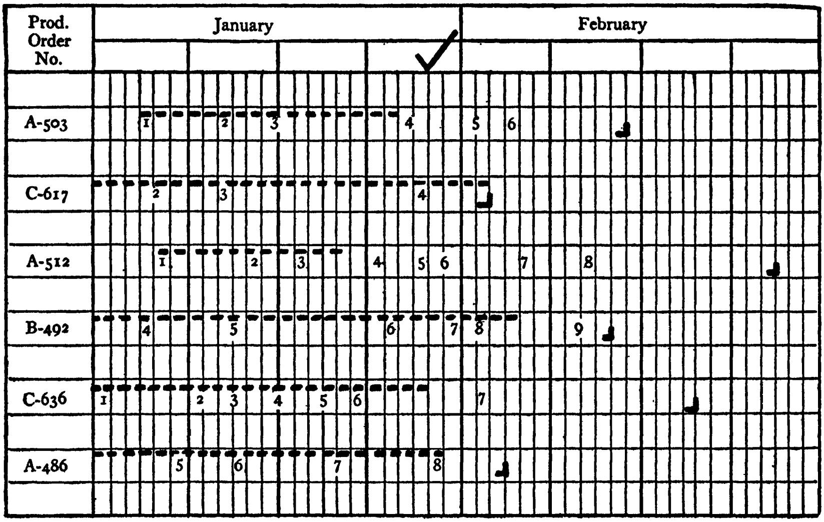


FIG. 28.—Illustrating a form of Gantt Progress Chart as used by the production-planning department. Explanation of the chart: The numbers opposite each production order number represent the operation numbers for each operation which must be performed in the manufacture of the order. They are inserted under the date on which the operation should, according to the schedule, be begun. The mark (⌋) indicates the date on which the order was to have been completed. The heavy broken line indicates the progress which has been made to date. The mark (√) indicates the date on which this Progress Report was made. It will be noted that some orders are ahead, and some are behind, schedule.

tions for anyone who is to be intrusted with the task of designing procedures for a given enterprise.

Relation of Planning and Cost Departments.—Close harmony must exist between the production-planning and the cost departments. The ruling consideration, both in routing and scheduling operations, is to secure completion of the tasks specified within required time limits and at minimum cost. The choice of methods and machines often depends upon a knowledge of operating costs which must be derived from the cost records. On the other hand, the cost department is dependent upon the planning department for the collection of data concerning

production costs. Time cards and material requisitions which originate as production control devices, before completing their function, become the evidences from which direct labor and material charges are entered in the cost records.

Some have been so much impressed by the interdependence of these two functions as to maintain that they should be placed in the same de-

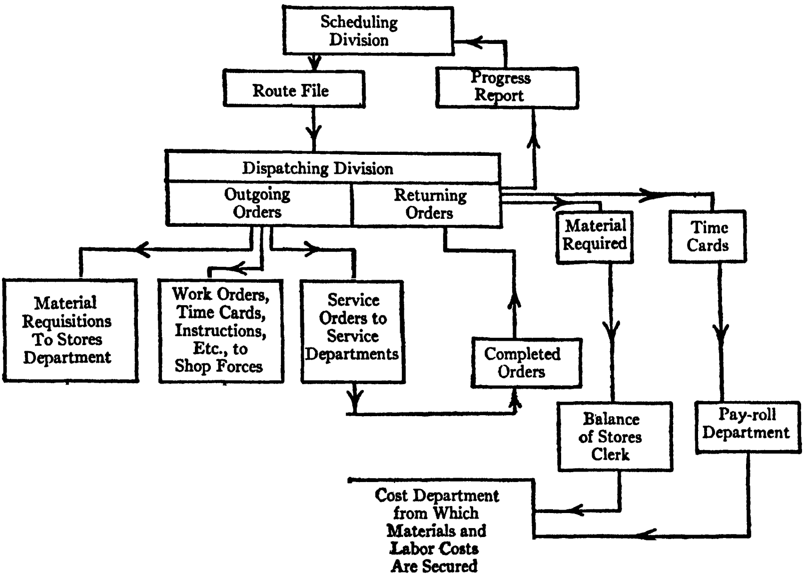


FIG. 29.—Chart showing disposition of production orders in the dispatching department.

partment. In the opinion of the writer, there are other considerations which outweigh this. As already stated, the cost department is, first of all, a division of the accounting system. Its activities are not necessarily confined to compiling merely "production costs," in spite of the fact that in practice this has been its most important sphere of usefulness. To be assured of their accuracy, cost records must be "tied in" with the general ledger. Unless valid reasons can be shown to the contrary, it may well be insisted that cost records should be maintained by the accounting department. It is, nevertheless, important that the peculiar bond between cost accounting and production-planning shall be recognized, and that a spirit of close co-operation between the two departments shall be fostered.

CHAPTER XVI

INDUSTRIAL INCENTIVES

Importance of Incentives.—Incentive is the unseen force which drives the workman to do his best. Everyone, no doubt, possesses some natural instincts of craftsmanship. Everyone feels some sense of pride in accomplishment and is moved by some inward cravings for the esteem of his associates. From such sources does all initiative and enthusiasm spring. But these native impulses must first be aroused and opportunity for their satisfaction found.

In modern industry, management alone can provide this opportunity. The employee has little control over the conditions of his employment. His share in the fruits of his labor is measured by the wage he receives. He cannot even choose his associates. But he may give or withhold his loyalty and whole-hearted co-operation as he chooses, and management for its own preservation must provide the means which arouse whatever enthusiasm, imagination, and energy the worker may possess.

During the last half-century, industry has progressed more than ever before. This progress has come in large measure through the introduction of machinery, but mechanization alone cannot fully explain the remarkable increase in productivity which we have witnessed. Management has contributed its share, and through it the worker himself has become more efficient—so much more so, in fact, that labor costs have continually declined in spite of ever rising wage scales. That such a relationship between high wages and low labor costs might be expected to exist was not a new idea, of course, for it was merely the demonstration of a principle which was clearly stated by John Stuart Mill many years before and later remarked upon by Babbage,[1] Schoenhof,[2] and others; but it seems, nevertheless, to have attracted little, if any, attention from "practical" men of affairs until the rising element of overhead cost resulting from industrial mechanization served to emphasize the importance of large output and placed a premium upon

[1] C. Babbage, *Manufacturing* (1836).

[2] J. Schoenhof, *The Economy of High Wages* (1892).

labor efficiency. Then it was that management began to take seriously Frederick Taylor's blunt statement that "men will not do an extraordinary day's work for an ordinary day's pay,"[1] and the modern high-wage policy became firmly fixed in the minds of employers largely because of the growing conviction that extraordinary effort can be induced only by extraordinary incentives.

Different Types of Incentives.—In ancient times, fear of punishment probably constituted the chief motivating force relied upon by the master in dealing with his servant. Some more enlightened urge, such as pride in workmanship or *esprit de corps*, may have occasionally inspired even the slave; but these positive incentives were, in all probability, chiefly a by-product of free institutions. Fear of physical punishment drove the slave to his task, just as fear of unemployment may and does constitute a powerful incentive in the modern factory worker's life. But neither the free workman nor the slave is inspired to do his best by these motives, nor can purely negative measures be relied upon by management to secure the desired end. Memory of the lash very likely had little influence upon the pace set by the slave when the slave-driver was absent; and the risk of being fired is borne lightly by the modern worker when employment is to be had elsewhere, and especially so if other more positive incentives to continue in his present employment are lacking.[2] Incentives of a punitive sort, such as threatened fines or loss of status, never have and never will inspire a human being to put forth his best effort.

The effectiveness of a negative incentive, such as certainty of discharge for failure to meet accepted standards of performance, is directly proportional to the relative desirability of the workman's present employment. No workman cares greatly about losing his job when that job does not seem worth the keeping. If the fear of being fired is to have much force as an incentive, the employer must make sure that the employment he offers is attractive. Many different considerations influence the workman in his attitude toward his job. The promise of

[1] F. W. Taylor, "A Piece Rate System," *Transactions of the American Society of Mechanical Engineers*, XVI (1895), 873.

[2] It is true, of course, that every positive incentive has its negative aspect. The promise of a reward for accomplishing certain results is all the stronger because of the knowledge that in the event of failure of accomplishment the reward will not be forthcoming. Such a stimulus is negative in character but bears no implication of punishment and hence does not incite resentment, as is almost inevitable where punitive measures are employed.

security in old age, a pleasant working environment, regularity of employment, opportunity for promotion—"welfare work" in the best sense of that much abused term—all tend to breed loyalty and a community of interest which impresses the worker with the desirability of his job and thus constitute a positive incentive for him to maintain the required standards of performance.

Most important of all, however, is the wage contract itself. Someone has said that "the supreme factor in human endeavor is self-interest," and nowhere is this self-interest of the worker so keenly felt as in connection with the wages he receives. Other non-financial incentives are important as supporting measures; but rarely, if ever, can they be substituted for a high wage.

Any form of financial compensation provides some incentive to work, of course; but to be most effective, it is contended, the amount of the reward must be directly proportional to the work accomplished. Hence extra remuneration for accomplishing or exceeding certain definite work standards is often held out as an incentive to exceptional performance. All so-called "wage-incentive plans" are based upon this fundamental formula. The differences in such schemes are differences in application rather than in principle or objectives.

Tests of Incentive Value.—The purpose of an industrial incentive scheme is to stimulate the worker to greater effort and co-operation by means of a direct appeal to his self-interest to improve his own status and, at the same time, reduce the costs of production to his employer. Such a plan in its very essence must be of mutual benefit to be successful; conceived and inaugurated by the employer from purely selfish motives, to be sure, but none the less making a direct appeal to the worker's interest in his own well-being. Unless the plan reduces the costs of production, it cannot be justified from the employer's point of view; unless it indicates clearly to the employee how his own status may be improved, it cannot but fail to supply the needed stimulus to greater effort.

To provide this desired stimulus certain definite characteristics are essential:

1. The provisions of the plan must be directly related to the worker's own welfare. This is fundamental. Any plan which attempts to run counter to human nature to so great extent as to appeal primarily to any motive except self-interest is predestined to failure.

2. The plan must recognize a direct relation between the workman's efforts and his individual reward. The reward must be won or lost through his own efforts. Furthermore, it must be something which he has a right to expect only if he earns it. A profit-sharing scheme in which the worker's share and that of his fellow-workers bears no direct relation to their respective efforts is much inferior in incentive value to a payment of extra wages for exceeding some specified standard of output.

3. The more immediate the reward the greater is likely to be its incentive value. The effects of most stimula are of short duration. Pressure must be continuously applied if sustained effort is to be secured. The prospect of a reward to be received as soon as earned is of much greater value than one to be received at some future date.

4. As the upper limit of accomplishment is approached, each increment of output requires greater stimulus than the one preceding. In other words, it is likely to require greater additional reward to induce a worker to produce an additional unit of product as he nears the end of his allotted task than to induce him to produce one more unit at the beginning. This fact is recognized in many wage plans in which the slope of the earning curve increases as output is increased.[1] Such a plan is based upon correct psychological principles if it is the purpose of the scheme to secure maximum expenditure of effort upon the part of the worker.[2]

5. An incentive plan must be simple and easily understood by the workman. Mathematical complexities have doomed many an incentive plan to failure by increasing the clerical labor of wage computations and by raising doubts and misunderstandings in the minds of suspicious and untutored workmen.

6. An incentive plan must appeal to the workman's sense of fairness and impartiality. Failure in this respect transforms that which was intended to be an incentive into a positive irritant, thereby defeating the purpose it was intended to serve.

[1] Professor Lytle (*Wage Incentive Methods*, p. 423) has aptly stated this principle in the following terms: "The older emphasis of labor costs rather than the new emphasis of total cost led to the popular conception that an incentive should increase less rapidly than production. The correct postulate is that an incentive should increase as rapidly and, when possible, more rapidly than production."

[2] This conception of the purpose of an incentive plan is, of course, subject to qualification. Quality, as well as quantity, of output must be considered. Furthermore, a long-run view is essential. A plan which spurs the workman to the breaking-point, obviously, will defeat itself in the long run.

7. A proper incentive plan must be recognized as one possessing some degree of permanence. The practice of rate-cutting which has characterized many wage systems in operation has perhaps done more to wreck shop morale than any other factor in the relations of management and labor. As Taylor pointed out,[1] it springs directly from the ill-advised adoption of some incentive plan without first determining what constitutes a reasonable standard of performance, and even after thirty-five years this warning is still sometimes ignored. Rates are determined by past performance (as if no improvement was to be expected!); and labor, accepting management's promises in good faith, responds to the offered incentive only to be disillusioned by a cut in rates and the prospect of expending more effort for less pay. No wonder, under the circumstances, that "the plan defeats itself" and that "men deliberately regulate output at the point where they think their employer will let them alone."

8. An incentive plan of sustained effectiveness must provide promise of reward which may be won without in any way diminishing the chance of fellow-workers to win the same reward. The strongest incentives are those rewards which are attainable by everyone irrespective of the performance of fellow-workers. A prize which is given only to the one who excels may temporarily raise the general level of performance, but if employed continuously will soon lose the general appeal which is an essential element of an effective incentive system.[2]

Origin of Modern Incentive Systems.—The two fundamental bases of wage determination, time work and straight piece rate, are in all probability of equally ancient origin. Until about 1880 they seem to have been practically the only bases in use and even today constitute by far the most important methods of computing the wages of industrial workers.[3]

[1] *A Piece Rate System* (1895).

[2] The practice of offering a prize for the best individual performance among a group of workers may have distinct value, of course, under special circumstances, such as a selling campaign, for example. It appeals to an instinct, more or less developed in everyone, which Lillian Gilbreth has called "the love of racing" (*The Psychology of Management*, chap. ix).

[3] It is very difficult to determine, with any degree of accuracy, the relative importance of different methods of wage payment. It has been estimated, for example, that 40 per cent of industrial workers are on time rate, though there is some evidence that this estimate understates the case for this most easily computed method of measuring wages. Certain it is, that straight piece rate, in spite of all its critics, is much more used in the aggregate than any of the modern incentive plans.

The last decade or so of the nineteenth century, however, in many respects marked the beginning of a new industrial era. The cumulative effect of a half-century or more of pronounced progress in engineering science was beginning to make itself felt. Mechanical inventions, such as the electric motor and the development of new and better materials for machine design, gave new impetus to the mechanization of industry. Labor was becoming more articulate in its demands. Overhead costs were gradually being discovered, and the traditional conviction of management concerning the incompatibility of high wages and low operating costs was even being questioned.[1] Management itself was being caught up in this burst of progress, and after much heart-searching evolved the new philosophy of the scientific management movement. It is not strange, perhaps, that one of the first indications of the new attitude on the part of management was a quickening of interest in the matter of incentives, nor that this has continued ever since to occupy an important place in the thinking of business executives.

It was in 1888 that Henry Towne presented the plan that is generally recognized as the forerunner of all modern incentive plans.[2] This scheme, which he called "gain sharing," provided for the payment of regular wages (probably computed on an hourly basis) and in addition accorded to labor a portion of any savings in production cost which might be effected through reduction of labor and other expenditures. This share was to be apportioned among departments in proportion to their respective responsibilities for the savings accomplished and each department's share was to be, in turn, divided among foreman and workmen upon some preconceived basis. The originator, in describing his plan, wished it to be clearly understood that it was not to be confused with "profit-sharing,"[3] somewhat in vogue then as now, which indeed he roundly condemned in the following terms:

[1] One of the first discussions on record of this subject before a group of business men is a paper by W. E. Partridge entitled, "Capital's Need for High Priced Labor," *Transactions of the American Society of Mechanical Engineers*, Vol. VIII (1886). The discussion which followed the reading of this paper indicates that the idea was well received.

[2] *Ibid.*, X (1888), 600–626.

[3] Profit-sharing, which, as Towne pointed out, often has little real relation to performance and hence could not be regarded as an effective incentive plan, seems to have been fairly common at that time, though more so in France than in either Great Britain or America, as witnessed by William Kent in his paper, "A Problem in Profit Sharing," *ibid.*, Vol. VIII (1886), and Sedley Taylor, *Profit Sharing* (London, 1884). The discussion which followed Kent's plea in favor of the plan indicates that it was not highly regarded by many.

The surrender by the employer of any portion of his legitimate profits without assurance of an equivalent return from those on whom he bestows it is wrong in principle and often objectionable in practise. It may be commendable as an act of charity but offers no solution of the problem of providing incentives for increased efficiency.

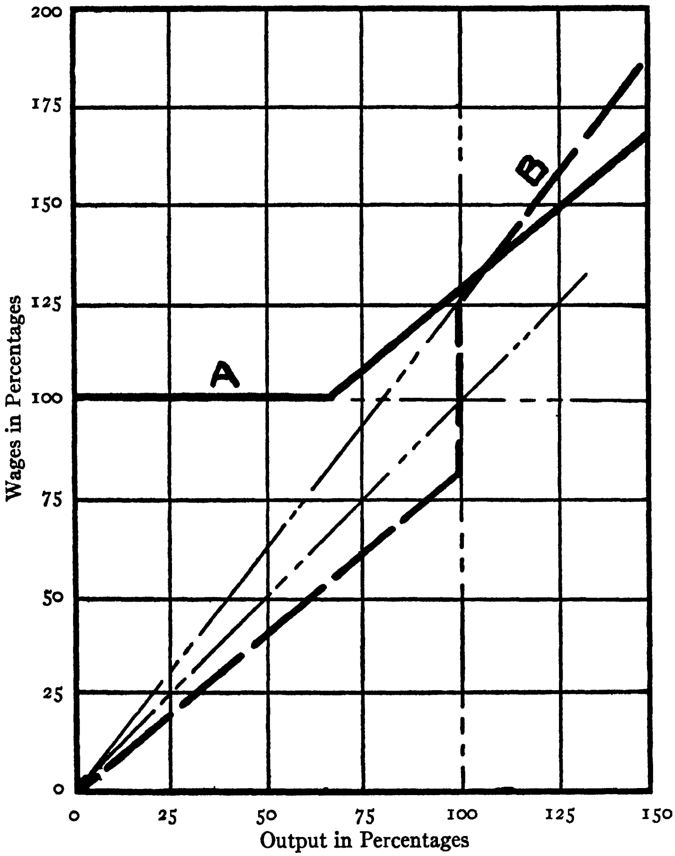


FIG. 30.—Chart showing Halsey and Taylor incentive plans

The making of the reward dependent upon the efforts of the workmen to reduce costs which characterizes Towne's scheme marks it as a true incentive plan, and his proposal was an important contribution to the thinking of his day. The practical benefits to be derived from such a plan may be seriously questioned, however, because of the remoteness of the reward and the difficulty necessarily experienced by the work-

man in relating his share of the reward with his individual efforts to promote efficiency.

Individualizing the Reward.—It was to be expected that some remedy for so glaring a weakness should soon be found, and thus three years later a plan was proposed in which the premium or "gain-sharing" of each workman was to be measured by his own efforts.[1] In the beginning, Halsey, who was the originator of this plan, seems to have had little thought of sharing with the workman in any definite ratio, merely having told his workmen who were on day rate that for any time saved above the usual standard he would give them five cents per hour extra pay. This, at the hourly rate then in common use, happened to be $33\frac{1}{3}$ per cent of the regular wage, and hence suggested the adoption of a definite sharing ratio. The plan appears to have been successful, and from this beginning developed the so-called "50-50" gain-sharing plan in which a minimum daily wage was guaranteed and any saving arising from production in excess of the accepted standard of performance was shared by employer and employee on a 50-50 basis.[2] The resulting earning scale is shown by curve *A* in Figure 30.[3]

The originator of the plan apparently had no fixed ideas as to the proper proportions for employer and employee, merely stating that "if the premium is too high the employer simply pays more than it would be necessary for him to pay."[4] Obviously, however, such a plan is less liberal to the employee than the straight piece rate by which the worker receives all the benefit from a saving in labor. This, indeed, in the mind

[1] F. A. Halsey, "A Premium Plan for Paying Labor," *Transactions of the American Society of Mechanical Engineers*, Vol. XII (1891). As hinted above, and as clearly suggested by the discussions which followed Halsey's presentation of the plan, the chief difference between this and Towne's plan lay in the choice of units. In Towne's plan the share was determined by the showing made by the several departments, whereas Halsey "individualized" the reward. The evidence clearly shows, however, that the two plans were developed entirely independently of one another.

[2] It should be noted that the standard in this case was ordinarily based upon past performance and not upon a scientifically predetermined conception of what constituted a fair days' work. In this respect, this and other early plans differed fundamentally from some later plans, of which that of Taylor was the first.

[3] Like all incentive schemes, this curve has been subjected to numerous variations. Both the sharing ratio and the daily base wage have been altered to meet local conditions. A step bonus of varying amount to be given when standard output is reached has also sometimes been used with this general type of plan.

[4] *Transactions of the American Society of Mechanical Engineers*, XII, 760.

of the originator seems to have been of great importance. "The difficulties of the piece work plan," contended Halsey, "spring from the fact that when the piece price is once set, an increase of effort by the worker redounds to *his own* benefit alone—the employer having no sharing in the saving of time, and cutting the piece rate becomes the only method of reducing cost."[1] On the other hand, said he, "the very purpose of the gain sharing plan is to avoid the necessity for cutting rates by dividing the savings between employer and employee."

The argument was fallacious, of course, since, even if the employee receives all of the saving in unit labor cost, the employer may still continue to realize a saving in total unit production cost on account of the declining amount of overhead chargeable to each unit, and would not accordingly be under as great a necessity for cutting the rate as Halsey would have us believe.[2] There is, in fact, no reason for assuming that the relatively weak incentive of such a plan will invariably spur the worker to expend the same effort he might gladly expend under the stronger stimulus afforded by a curve of steeper slope. As a result, total unit costs might in reality easily prove to be as high with one plan as with another.

The Rate-cutting Evil.—It is interesting to note to what extent the prevalent practice of rate-cutting affected the thinking of industrial executives of forty years ago. Even the most enlightened often found difficulty in believing that an employer might well pay his workmen a wage which considerably exceeded the current market rate for the purpose of inducing them to put forth extraordinary effort. Nearly all of the originators of early incentive plans clearly saw the evils of rate-cut-

[1] *Ibid.*, p. 756.

[2] Halsey may perhaps be excused for apparently falling into the common error of assuming that management has little to gain from increased output if unit labor costs are to remain constant, and hence must of necessity cut the rate. The feeling that high wages must bear some definite relation to high production costs under all circumstances was still very strong forty years ago, and indeed had much more to be said for it then than now, since fixed overhead (in which substantial savings to the employer are to be realized from large output) were not nearly as important relatively as they are today.

It should be emphasized, however, that it is declining total unit costs which are significant to management, and to accomplish this result an incentive plan which allotted to the worker even more than the total saving in labor cost might conceivably (though not probably) be justified if such an added sharing in overhead savings were necessary to induce the extra effort on the part of employees.

See C. W. Lytle, *op. cit.*, pp. 281–86, for a discussion of the Ficker machine-rate plans, which under certain circumstances may be made to yield this result.

ting, however, and contended that the plans they proposed provided a solution for this most vexatious labor problem of their day. The originator of one early plan even went so far as to violate well-recognized principles concerning incentives by proposing an earning scale such as

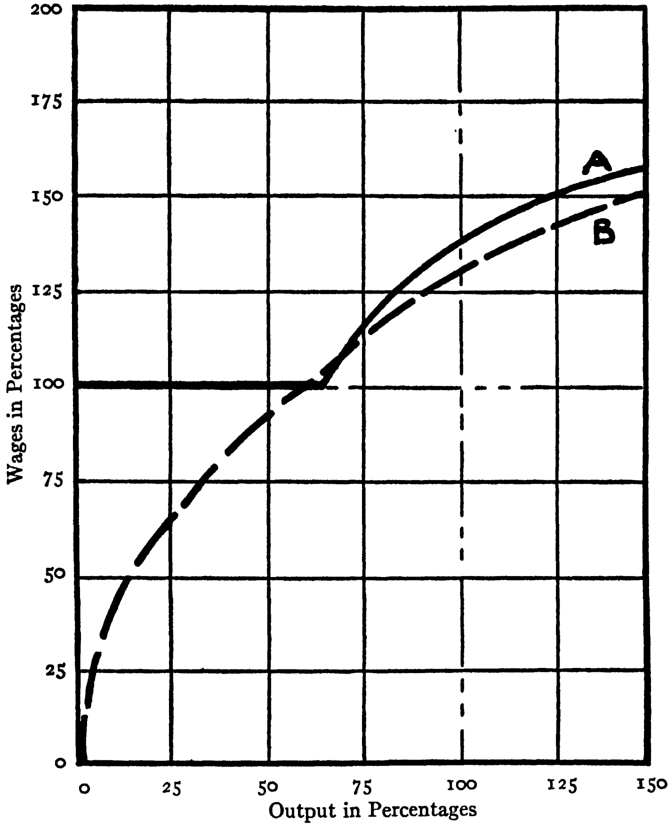


FIG. 31.—Chart showing Rowan and Barth incentive plans

shown by curve A in Figure 31, with which the incentive is deliberately and progressively reduced in the higher ranges of production.[1]

[1] This scheme, known as the "Rowan plan," was developed by James Rowan of Glasgow, Scotland, in 1898. By it the daily earnings at and above standard are computed by the formula:

$$\frac{\quad}{U_a}$$

in which W_a = daily wages received, W_b = base-rate wages, U_a = units of output actually produced, and U_s = standard units of output. In discussing later plans, the formula will be

This plan was defended by the originator upon the grounds that it would remedy the rate-cutting evil by preventing workmen from securing a return which was too much in excess of what was generally accepted as a reasonable wage. In other words, rate-cutting was to be abolished by deliberately withdrawing the incentive from the more efficient and ambitious workmen who had heretofore made rate-cutting seem so necessary! Doubtless it would accomplish this result, but as an incentive plan it obviously is not above criticism.

The Scientific Determination of Objectives.—It remained for Frederick Taylor, with his usual keen discernment, to suggest that the solution of the problem lay not in discouraging superior workmen but in determining beforehand what constituted a reasonable day's work. Thus far, all incentive plans, including piece rate, had been based upon a standard of performance which had prevailed prior to the introduction of the plan in question. It was but natural that, after any new plan was introduced, output would be greatly increased if the plan had superior incentive value, and that the best workmen, at least, should earn a great deal more than the current market rate for men of the same class who had been offered no such incentive. Under such circumstances there was a great temptation, though perhaps an unreasonable one, for the employer to protect his own interests by a downward revision of the rates.

Taylor, who apparently had little fear of high wages per se, contended, on the other hand, that the proper attack on the problem was to adopt as standard not the output which had been obtained from men working under improper incentives but rather that which ought to be secured after proper incentives had been provided.

stated in these terms, though it should be noted that it sometimes is more convenient to express wage formulas in terms of "hours saved" instead of "units of output actually produced." In these latter terms Rowan's formula would, of course, be as follows:

$$E = H_a R_h + \frac{(H_s - H_a) H_a R_h}{H_s},$$

in which E = earnings in dollars, H_s = hours standard, H_a = hours actual, R_h = rate per hour in dollars. The foregoing formula results in an earning curve rising sharply from standard but decreasing gradually as output is increased. Wages could not under any circumstances exceed twice the base rate. It is probable that for outputs ordinarily secured by these plans, the incentive value of this and the Halsey plan would not differ greatly in practice. See *Trans. of the American Society of Mechanical Engineers*, Vol. XXV (1903); also C. W. Lytle, *op. cit.*, pp. 290–301.

This was a revolutionary proposal in that it suggested for the first time that by scientific analysis one might determine in advance what a workman might reasonably be expected to accomplish. The process involved careful time study and method analysis, as well as complete standardization of all conditions surrounding the work, and placed squarely upon the shoulders of management much greater responsibility for results than employers theretofore had been accustomed to assume.[1]

Many of the implications of this proposal comprise another story which we have already considered in another connection. It must necessarily occupy a prominent place in any discussion of incentives, however, since for the first time the suggestion was made that the primary step in devising an incentive plan is to formulate a careful definition of objectives which the plan may reasonably be expected to accomplish. With the objectives thus determined, Taylor proposed to offer, first, a strong incentive for men to reach this standard and indeed to exceed it in so far as they were able; and second, to exact a penalty in the form of a very low rate from those who could not or did not attain the desired accomplishment. The earning curve thus devised, in effect constituted a two-piece-rate scale, as shown in curve *B*, Figure 30.

The general plan seems for the most part to have been well received, though there is some evidence that its full implications were not fully recognized by many of Taylor's contemporaries—a circumstance which he himself observed with keen disappointment.[2] The chief criticisms, in fact, were leveled, not at the proposal to load upon management the enormous additional burden of scientifically determining proper standards of performance, nor at the suggestion that extraordinary induce-

[1] This insistence upon the predetermination of output standards by scientific experimentation, which characterizes not only Taylor's incentive plan but many of more recent origin as well, is the reason for the common designation of these as "scientific" plans in contradistinction to other "unscientific" plans which contemplated no such laborious procedure in determining the standard. On account of the implication of superiority which in the case of some so-called "scientific" plans is not altogether merited, this means of characterization does not seem to be a particularly helpful one.

[2] The student who is interested in the evolution of wage incentive methods can find no better employment than to trace this early thread of development as reflected in the various papers presented before the American Society of Mechanical Engineers. The discussions which invariably followed the presentation of these early papers give one a good cross-section of the thinking of industrial managers of that day and are particularly helpful. Nearly all of the early incentive plans were first published in the *Transactions* of this Society.

ments are essential to secure extraordinary effort, but at the severe penalties exacted if the standard of performance was not reached. Under ideal conditions, these objections might be more fancied than real, it is true, for with careful recruiting and training of workmen, as was contemplated by Taylor, a superior working force might be developed which would without exception be capable of reaching the desired standard. But unfortunately, ideal conditions cannot always be maintained in the hurly-burly of the shop; and thus a considerable proportion of the workmen might easily find themselves in the difficult position of not being able to earn sufficient wages to enable them to improve, or even to maintain, their customary degree of physical efficiency. Especially would this likely to be true for a man in training who had not yet attained his full capacity. Conceivably, such a man ought to receive more immediate and sustained encouragement than is afforded by the penalizing rate of the lower scale which is characteristic of this plan.

Attempts To Protect and Encourage the Substandard Worker.—This real problem of the beginner prompted Carl Barth, an associate of Taylor, to suggest a plan with an earning curve of the hyperbolic type, as shown by curve *B* in Figure 31.[1]

The steep slope which is characteristic of this curve at low production levels provides an especially strong incentive for improvement, and thus lends the element of encouragement which was lacking in Taylor's plan at a crucial period in the workman's employment. At higher levels the slope of the curve is even less than that provided by Halsey's plan, and the scheme is subject to much the same criticism as may rightly be made of Rowan's proposals previously mentioned. In fairness to its author it should be stated that he obviously never intended that it should be used except under special circumstances. For workmen who have not yet acquired the skill requisite for high production it is undoubtedly one of the best incentive plans ever proposed.

The attempt to deal more understandingly with the problem of the substandard worker who fared so poorly under the differential piece rate of Taylor has been responsible for some of the most significant

[1] With this plan, daily wages are computed by the formula:

$$W_a = W_b\sqrt{\frac{U_a}{U_s}},$$

in which the symbols are the same as previously used. (C. Barth, "A Suggestion for a Premium System," *Management and Administration*, July, 1924, pp. 71–73.)

contributions to the literature of incentives since Taylor's day. Two such contributors, namely, Gantt and Merrick, deserve special mention.

Perhaps no one has shown more capacity for seeing eye to eye with both management and labor than has H. L. Gantt. An associate of Taylor, he sympathized perfectly with the latter's attempt to deal rationally with the problems of management. At the same time he showed much greater aptitude in his relations with employees. He, too, insisted that management must assume responsibility for standardizing conditions and creating an environment in which a high level of performance might be expected but was unwilling that the worker should be penalized so heavily when inaptitude, lack of training, or failure of management made this high standard of performance unattainable. Most significant of all, perhaps, he was not content to rely solely upon the stimulus of high wages and devised what was in reality a complete and comprehensive system of industrial incentives. With keen psychological insight he contrived means for showing comparat vely the output of individual workmen, and by carefully prepared propaganda[1] appealed directly and strongly to that sense of healthy rivalry and pride of performance which every right-minded worker, when properly directed, may be made to feel. He emphasized the importance of adequate training and, by devising a system of foreman's bonuses, stimulated these representatives of management to assume responsibility for adequate instruction of employees. In short, every known legitimate device, both financial and non-financial, was to be used to secure a high level of efficiency in the shop.[2]

The specific wage plan which he proposed was a combination of time

[1] In referring to such devices as propaganda, there is no intention of suggesting the derogative implications which this term so often merits. When employed in conjunction with adequate financial compensation and without hypocrisy, it is a perfectly respectable incentive device. Many instances could doubtless be cited where its use has been amply justified by results.

[2] The writings of H. L. Gantt comprise some of the most stimulating pages in the entire literature of scientific management. His contribution was no mere wage-incentive plan but a complete and practical system of shop management. Next to Taylor himself, modern production management probably owes more to him than to any other man. His work and manner of thinking may be traced in the following published papers:

"A Bonus System for Rewarding Labor," *Transactions of the American Society of Mechanical Engineers* (1902).

"A Graphical Daily Balance in Manufacture," *ibid.* (1902).

"Modifying Systems of Management," *ibid.* (1904).

"Training Workmen in Habits of Industry and Co-operation," *ibid.* (1908).

Much the same ground was covered, as well as some new materials in his book, *Work, Wages, and Profit* (1910).

pay and piece rate, in which a minimum day wage was allowed below standard, to be followed by a step bonus at standard, and a high piece rate approximating that which Taylor had proposed for performance above standard. The resulting earning scale is shown by curve *A* in Figure 32.

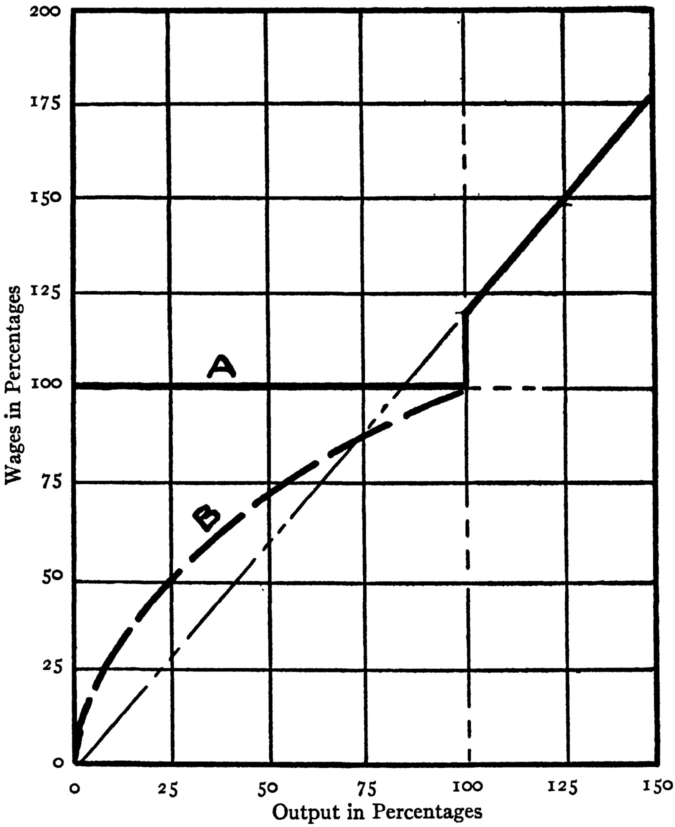


FIG. 32.—Chart showing Gantt and Barth-Gantt incentive plans

Gantt, himself, seems to have modestly disclaimed any special credit for the plan, and indicated that it "was intended as a means of upgrading men to the skill required to work under the Taylor differential piece rate plan, and to be used temporarily during the installation of Taylor methods."[1] It appears, however, to have sufficiently distinctive qualities to stand upon its own merits. In spite of the fact that it apparently

[1] C. W. Lytle, *op. cit.*, p. 209.

is little used today in its original form, traces of its influence may be clearly seen in many wage schemes of more recent origin. Valid criticism might be leveled at its characteristic feature upon the ground that a guaranteed minimum wage is unnecessary and tends to encourage the

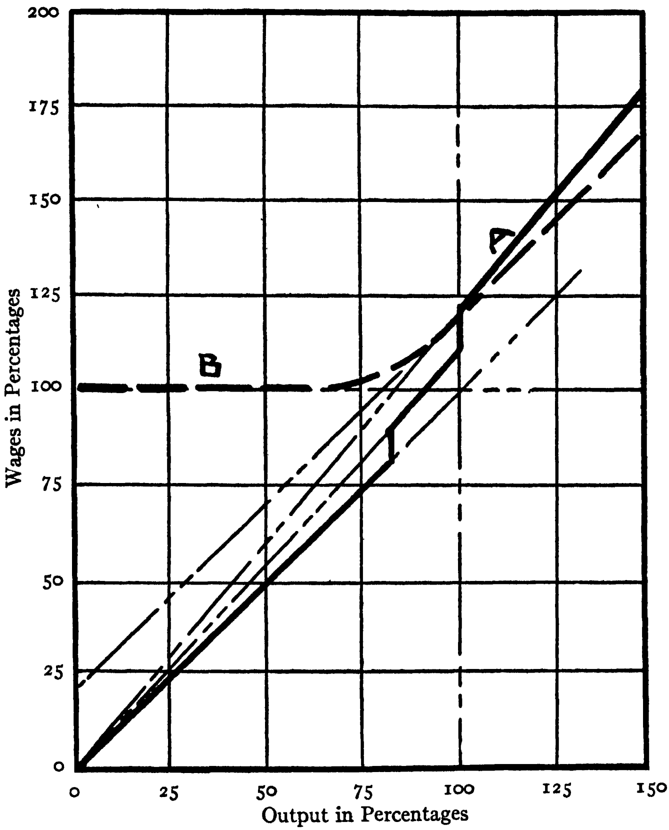


FIG. 33.—Chart showing Merreck and Emerson incentive plans

less ambitious workman to content himself with something less than standard performance. But if this guaranteed return were to be deliberately placed at a low level and intelligent use were to be made of non-financial incentives such as Gantt proposed, this particular feature might be made a source of strength rather than weakness.[1]

[1] Professor Lytle (*op. cit.*, p. 344) has suggested an interesting combination of a modified Barth curve below standard with the step bonus and high rate of Gantt at standard and above, as shown by curve *B* in Figure 32. There is much which might be said in favor of such a proposal.

Merrick attacked the problem in radically different fashion by discarding the time wage entirely and substituting therefor a multiple piece-rate plan, as illustrated by curve *A* in Figure 33.[1]

For production above standard the earning curve with this plan is identical with that of Gantt; but for low production (specifically up to five-sixths of standard production) basic piece rate is used, which, it will be remembered, provides a stronger incentive than the punitive rate of Taylor. The step bonus, which is of the same proportions as that of Gantt, is divided into two equal parts, and the wage curve between these two bonus points is an intermediate piece rate. Since all three piece rates will, if prolonged, pass through the point of origin upon the chart, the resulting earning curve is one of gradually increasing slope as output is increased. This feature, together with the step bonuses which provide strong and concentrated impetus at critical junctures in the workman's performance, make the plan a particularly good one,[2] though it seems that it has been less used in practice than some other schemes of more doubtful merit.

Other Applications of Well-recognized Incentive Principles.—The psychological value of continually holding before the worker a reward which increases at an accelerating rate as output is increased, as is contemplated by an upward-turning earning scale, has been recognized by many of the originators of modern incentive systems. Some of these have followed in the footsteps of Taylor and, like Merrick, have definitely committed themselves to the piece rate by devising a multiple scale with step bonuses of varying proportions introduced at crucial points in the workman's task. Every additional rate adds to the complexity of the plan, but undoubtedly there are occasions when this increased complexity is justified by the stronger appeal which can be made to superior workers by the promise of a progressively increasing rate of return.

Others have abandoned the piece rate and used a number of time rates instead, each separated from the one preceding by an appropriate

[1] D. V. Merrick, the originator of this plan, has never given it much publicity, merely having referred to it as a "differential piece-rate plan" with the obvious implication that it is simply an adaptation of Taylor's plan, which, of course, is true. It is described in his book, "*Time Studies for Rate Setting*" (1920), pp. 346–48.

[2] It would perhaps be even stronger if the second bonus were to be made of greater magnitude than the first. There is no reason, of course, why this variation might not easily be introduced.

step bonus. The horizontal rate scale of time pay offers no incentive to increase effort, of course; but when this scale has been broken at frequent intervals by a substantial bonus, even the dullest and most sluggish workman can clearly see the advantage of increasing his output.

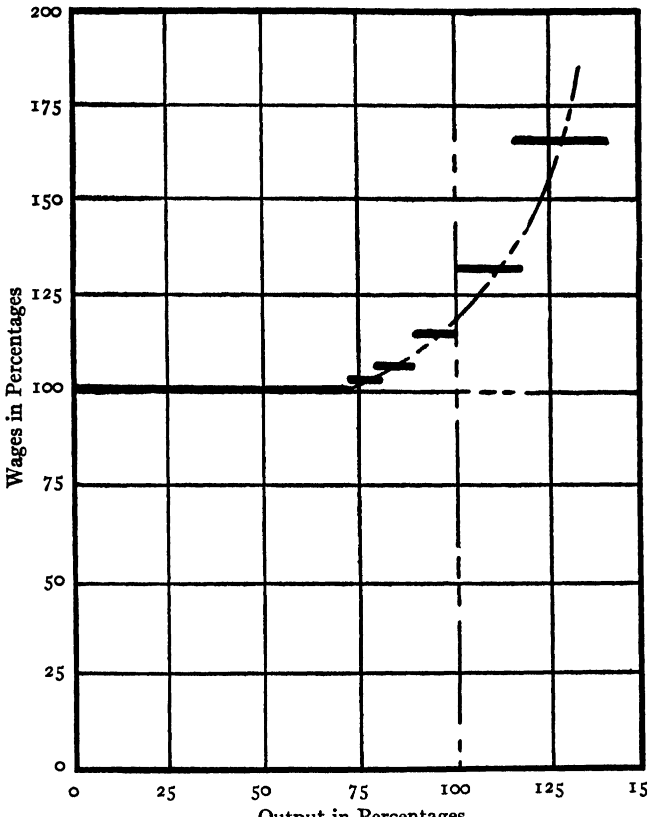


FIG. 34.—Chart showing differential geometric day-rate incentive plan

The plan is so easily grasped by the men in the shop, and the wages are so easily computed, that one is led to wonder why such schemes have not been more generally used, especially since by the exercise of a little ingenuity they may be varied and adapted to provide an incentive of almost any required strength. By devising a series of bonuses increasing in geometric ratio, as shown in Figure 34, an upward-turning curve is approximated. At the same time, the workman is continu-

ously confronted by a series of reasonably attainable objectives, each of which is made attractive by the promise of a substantial increase in pay.[1] This plan, it would seem, might be adapted to almost any situation and be made to accomplish almost anything which a wage incentive system may be expected to accomplish.

A number of industrial engineers have employed a smooth curve with varying degrees of success in their efforts to spur the worker to greater performance. Perhaps the most widely known plan of this general type is that devised by Harrington Emerson, as illustrated by curve *B* in Figure 33.[2]

This particular plan is somewhat reminiscent of Gantt's proposal, though at first glance the two plans are of radically different appearance. Both provide a minimum guaranteed daily wage of the same amount, and the upper section of the curve in both starts at the same point upon the earning-output scale. Instead of the step bonus of Gantt, however, Emerson has employed an upward-turning curve of circular type connecting the two tangential sections. This changing rate begins at very low production (approximately two-thirds of standard) and provides for slight increments in wage until standard production is reached, after which the scale follows a straight line which is parallel to, though 20 per cent above, basic piece rate.[3]

The chief distinctive feature of this plan is, of course, the provision of a gradually increasing bonus at very low production. There may be some advantage in offering encouragement at this point, though there is reasonable doubt whether the relatively slight progressive increases in compensation provide an incentive which is superior to a sudden increase of equal total amount at standard production. Furthermore, since above standard, where strong incentives are likely to be most needed, this particular plan offers increments of no greater magnitude than basic piece rate, it is difficult to discover wherein it is much superior to some earlier and less complicated plans. It must be admitted,

[1] Professor Lytle, who is credited with devising this plan in 1925, states that while it was aimed particularly at sales work it is not different in principle from any standard time plan. See Lytle, *op. cit.*, pp. 156–58.

[2] H. Emerson, *Efficiency* (1909), pp. 218–27.

[3] This section of the scale differs from that of Gantt, which was a true piece rate which would, if prolonged, pass through the point of origin upon the chart. Accordingly, for high production Gantt's curve is of steeper slope and provides a stronger incentive than that of Emerson.

nevertheless, that either because of greater intrinsic merit or because of more intensive promotion by its advocates, this has become one of the best known of modern incentive systems.

Many Other Wage Plans Available.—It is not proposed that we carry further the examination of different incentive plans. During the decade prior to 1920 these appeared with monotonous regularity, and each has its own enthusiastic supporters.[1] Many of these later plans obviously have been designed to meet some special condition in industry. Some are merely adaptations of somewhat doubtful merit of earlier plans. And a few, it must be concluded, have been devised chiefly because industrial engineers have been quick to recognize the superior sales strategy of being in a position to offer what seems to be a distinctive product to their clients.[2]

The specific plans which have been examined in some detail have been selected for this purpose not because they necessarily represent the best that have been proposed but because it is thought that they do illustrate better than any other the development of wage-incentive theory. No one of these plans may be said to be ideal, for, if anything has been learned about incentive plans, it is that no single plan will unfailingly meet all the varying requirements and conditions of industry. Taken as a group, however, they do illustrate the application of all recognized principles of financial incentives and thus serve our

[1] Adolph Langsner, in a recent investigation, discovered thirty-six different incentive plans, of which twenty-seven are to be identified by the names of their authors and nine are of the "so-called home brew type, with some fancy name." "(A Survey of Compensation Methods and Incentive Plans in a Variety of Industries," *Report of the Proceedings, Sixteenth National Convention, Society of Industrial Engineers* [1929]). Practically all of these plans are described and compared in great detail by C. W. Lytle in his book, *Wage Incentive Methods*, to which reference has been made many times in this chapter. This is the most authoritative and complete manual on the subject which has ever been written.

[2] It should not be concluded that it is the writer's intention to condemn in sweeping fashion all wage plans which are not specifically mentioned in these pages. The desire to adapt the plan of wage payment to conditions as they exist in each organization is entirely commendable. What is to be deplored is the endless multiplication of plans of very little distinctive merit. Such a tendency, which happily seems to have about run its course, is unfortunate and likely to lead to much muddled thinking. Managers, when continually subjected to the blandishment of high-powered salesmanship, sometimes conclude that the one thing needful is to adopt some certain wage-payment plan, whereas the evidence clearly shows that the particular plan to be used is much less important than wise administration and keen appreciation of the value of other forms of incentive. The poorest of wage-incentive plans when used by an otherwise discerning management will give vastly superior results than the best incentive plan ever devised when placed in incompetent hands.

present purpose. It is much more important that students and production executives understand these underlying principles than that they be intimately acquainted with all the numerous applications of these principles which have been proposed.

Method of Comparing Incentive Plans.—A common error into which many have fallen when comparing such plans is the conclusion that labor costs may be lowered by the simple expedient of adopting a plan with a low earning curve. Nothing could be farther from the truth. Obviously, it is not to be inferred that one plan will give lower unit costs than another merely because it happens to be drawn at a lower level upon a chart. Unit operating costs including both labor and overhead, are a function of output; and, assuming that management is incurring no more expense than must be incurred, these unit costs can be reduced only by increasing output.

In devising any wage system, one must first determine one's objective in terms of the output which may reasonably be expected. This standard must, of course, be an attainable one in any case. Workmen cannot do the impossible. Should management fail to provide the working conditions requisite for standard performance, no incentive plan will work. But even assuming that all such managerial responsibilities have been fully met, the workman must be induced to put forth the effort required to reach this standard of accomplishment. And with any given condition of the labor market, approximately the same wage is likely to be required to induce maximum effort irrespective of how wages are computed. The value of a workman's services is determined in large measure by current market conditions, and, as one writer has aptly said,

> A moment's reflection should convince anyone that workmen will not cheerfully accept $1.50 in payment for $2.20 worth of work no matter which plan is used. It should be equally obvious that the management will not willingly pay $2.20 for work worth only $1.50 just because they are using some certain wage plan.[1]

The true test of superiority of one plan over another is not whether it will secure the desired standard of output for less money but whether it provides a type of incentive better calculated to induce workers as a group to attain the desired standard. Some plans, by their very na-

[1] A. G. Trembly, "Wage Incentive Formulae Compared and Evaluated," *Report of Proceedings, Sixteenth National Convention, Society of Industrial Engineers* (1929). This is the best brief discussion of methods of comparing incentive plans which has come to the attention of the writer.

ture, may tend to make the workman content with something less than standard performance. Some, by withholding needed encouragement from the beginner, may prevent him from acquiring skill ever to attain this objective. Again, by wrong incentives, some plans may induce quantity at the expense of quality, and thereby defeat their purpose. Such defects, if inherent in a plan, clearly mark it as inferior to others not so burdened.

This basis of comparison as applied to the several plans which have been considered is illustrated by Figure 35.

All, it will be noted, have been oriented by drawing the curves so as to pass through the point XY, X being the standard output objective and Y the wage found to be necessary to induce effort of that amount.[1] Below and above this point the curves do not coincide, of course, and hence the substandard worker would fare better with some plans than with others. But assuming, for the moment, that all are of equal incentive value, the average performance for identical groups of workers would in every case be clustered about the point where all curves converge.

The New Conception of the Standard Day Wage.—If the foregoing line of reasoning is correct, the question may well be asked, "Why bother about special incentive plans at all? Why not determine the objective and the wage necessary to induce such superperformance and hold every worker to that standard?" Such a decision would, in effect, constitute a reversion to a per diem wage—not the old day rate with which we have been familiar heretofore, it is true—but a day scale such as is represented by the line AB, on the chart, since no worker whose performance deviated much from standard would presumably be retained or long under such a system of wage determination.

The question thus raised is an entirely reasonable one, and the answer is that this is exactly what may happen under certain conditions.[2] These conditions are as follows:

[1] The standards X and Y have, of course, been arbitrarily chosen for illustrative purposes only, and do not coincide with the "100 per cent," "100 per cent" standards used in the charts previously shown in this chapter. How the proper values to be assigned to these symbols might be determined in practice is, naturally, a difficult question. X may be determined experimentally by the aid of time-and-motion-study technique. Y, however, depends upon so many variables both within and without the business that an accurate determination of how much must be paid in wages to induce a given output is well nigh impossible. Suffice it to say, that management must (no matter how imperfectly) make some such determination every time a wage rate is set.

[2] The well-known day-wage plan of the Ford Company is an example of this.

1. Manufacturing processes and methods must be completely standardized, else workers cannot be held at the desired standard of performance.

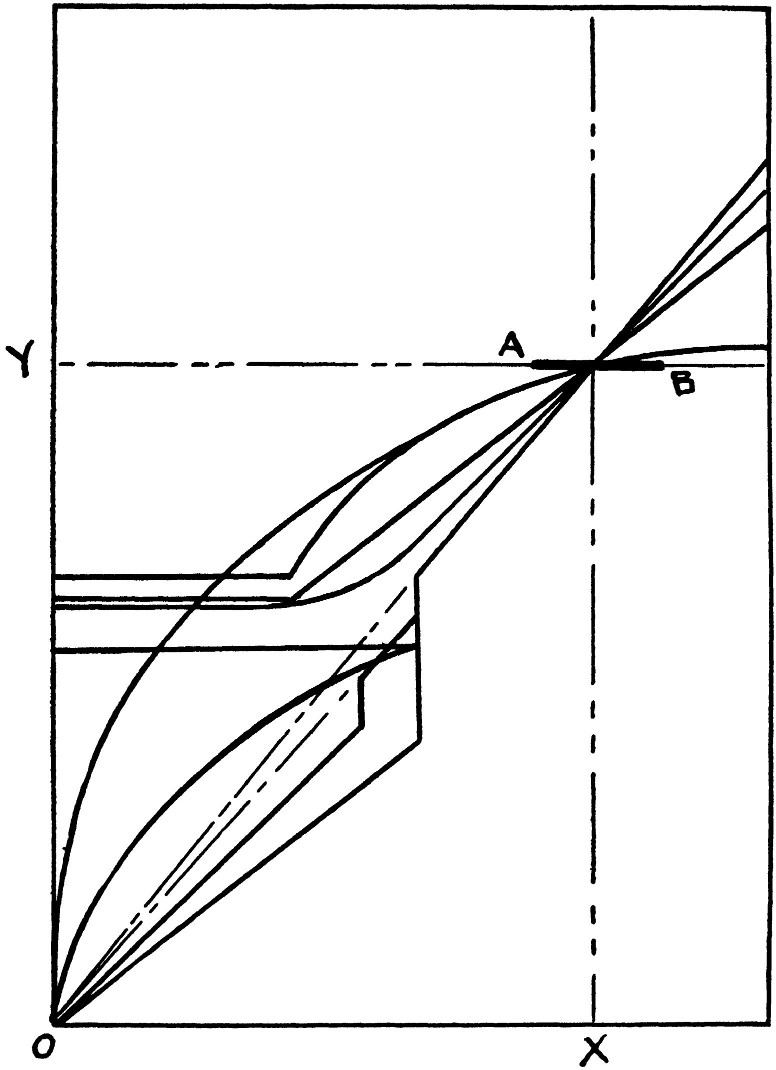


FIG. 35.—Chart showing method of comparing various incentive plans

2. Operations must be completely mechanized and organized in such a manner that the processes themselves set the pace for the worker.

3. The general conditions of employment must be made so attractive that employees are willing to submit to the rigid discipline necessarily entailed.

4. Training and skill must be standardized and all workmen must be capable of attaining the objective expected of them day after day.

The truth of the matter is, of course, that many industries are incapable of creating these special conditions. Most factory workmen are still (perhaps always will be) in a position to determine the pace at which they choose to work. Self interest, by the very nature of things, is their guiding motive, and the lure of a gradually increasing earning power is indispensable if they are to be held constantly at a high level of performance. As long as it is impracticable—as it is in many instances—to determine accurate standards of performance and to enforce the rigid discipline requisite for successful use of the high day-wage plan, it is likely that differential wage systems will continue to be held in high regard by production executives.

Modern Tendencies.—The present tendencies, if one may be permitted to speak of tendencies where so little uniformity is apparent in practice, are for wage incentive methods to become not less important but more so. Industry is undergoing profound changes in matters of organization, it is true. As specialization increases, workmen become more dependent upon one another. The collective efforts of the group rather than the will of the individual tend to determine output. But the same incentives which heretofore have been applied to the individual have been found to be equally effective in promoting group action, as witnessed by the increased use of the group bonus.[1]

Production executives are perhaps not so strongly partisan as they once were in their preferences for some specific plan. Rather, there seems to be a growing tendency to study the individual operations and to adapt the wage plan to local conditions. Finally, the teachings of Gantt are beginning to bear fruit. More and more, the wage incentive plan is coming to be regarded not as a cure-all for industrial ills but merely as one of a number of incentive devices, all of which have value in the endless struggle with inefficiency.

[1] Nearly any of the plans in common use may, by adaptation, be used as a group plan almost as well as for a single individual.

CHAPTER XVII

MEASURES OF PRODUCTIVE EFFICIENCY

Necessity for Measures of Performance.—Business management is always more concerned with the future than with the past. When laying plans, formulating policies, determining methods, establishing procedures, or assigning tasks to subordinates, it is only the operations of the future which can be influenced. Nevertheless, an occasional backward glance is essential. Everyone of these fundamental tasks of management is conditioned somewhat by past performance. Without a thorough grasp of what has already been accomplished, future operations can scarcely be directed intelligently. It is not sufficient for everyone in the organization to know what his duties are. Executives must be provided with means for determining whether these duties have been or are being performed, and, if not, what steps must be taken to secure performance. It is this requisite of efficient management which is to be considered in this concluding chapter.

Performance cannot be judged without a knowledge of facts, and our inquiry will thus hinge on two considerations: (1) what facts concerning performance does the production manager require, and (2) how must these facts be presented if they are to facilitate the forming of proper judgments. A thorough grasp of facts concerning operations is perhaps of no greater importance to executives now than it ever was, but the difficulties of acquiring this knowledge have increased enormously in recent years. In large organizations the production manager is considerably removed from the daily routine of the shop. He must chiefly rely upon reports which pass over his desk. If these are not properly conceived, he has no adequate measure of the performance of his subordinates and can scarcely be expected to formulate wise decisions with respect to future operations.

Requisites of an Effective Measuring Device.—This conception of the function of the reports of the production department has an important bearing upon their content. If they are the means through which performance is measured, the question may well be raised as to what are the requisites of an effective measuring device.

Perhaps the first requisite of all such devices is *simplicity*. Their purpose is to set forth relationships in quantitative terms. Production reports are tools merely, and, like all good tools, ought not to be so complex nor so burdened with meaningless refinements as to divert the attention of the user from the work in hand. There is a limit even to an executive's energies. These must be conserved and directed into the most fruitful channels. It is the executive's function to make decisions. His need for facts extends only so far as they enable him to choose wisely; and his time, therefore, should be spent in using facts rather than in searching for those which are significant.

The second requisite, no doubt, is *accuracy*. Misstatements and half-truths which are accepted as facts inevitably lead to unwise conclusions. When incorporated in a business report, they are likely to defeat the very purpose which it was intended to serve. Even if discovered, they breed contempt and lack of confidence in recorded data, and create an attitude of hesitancy in making decisions which is very damaging to efficiency.

Scarcely less important is the need for *relevancy*. Decisions which have been influenced by facts which have no bearing upon the point at issue are probably no better than if they had been influenced by actual misstatement. The cost of operating a given department, for example, is not a satisfactory measure of the department's performance if the cost has been influenced by expenditures over which the department has no control. Such elements are irrelevant for the purpose for which the resulting data are to be used.

Closely related to this last requisite is the matter of *timeliness*. Reports which are purely of historical interest do not satisfy the needs of the business executive. To him, facts are significant only when they enable him to direct current operations. Reports which reveal failures which it is too late to correct may be of value, of course, just as a post-mortem examination may be of value; they are of little use to the man who, had he known in time, might have prevented the failure.

The Standard of Measure.—Measurement is essentially a process of comparing the thing or tendency to be measured with some recognized standard. The performance of an individual or of a department can no more be measured without a suitable standard with which to compare results than can the length of a room be determined without a recognized standard of linear measure. It is necessary, therefore, first to

adopt some standard or standards, and second to arrange the facts regarding performance in a manner which will facilitate comparison. How the standard which is used has been determined is purely incidental. It may, as in the case of standard costs, be a norm derived from past experience to which suitable corrections for changing circumstances have been applied. It may be based upon performance under similar conditions in other plants. Again, it may, as has already been explained in the discussion of standards of accomplishment, be the result of scientific analysis and experimentation. The important thing is that it shall, for the time being at least, represent what is regarded as satisfactory performance.

Methods of Presenting Facts Concerning Performance.—The significant facts concerning production operations are nearly always in some measure related to one of the following questions: When or at what rate were these operations performed? To what extent have the resources or potential capacity of the plant been utilized? What has been expended in securing these results? Each of these questions has given rise to special types of measuring devices. The reports which set forth the facts needed in applying these different methods of measurement may be classified as follows:

1. Those pertaining to performance in relation to *time.*
2. Those pertaining to performance in relation to *potential capacity.*
3. Those pertaining to performance in relation to *cost.*

Measures of Performance in Relation to Time.—There are two important kinds of time relationships in which the production manager is interested. The first has to do with insuring that all related operations are properly synchronized. The second has to do with determining whether individual operations have been completed in the time allotted for their performance. The first is concerned primarily with time co-ordination, and incidentally with the efficiency of the plant as a unit. The second is concerned with the efficiency of the individual operation.

The importance of time co-ordination in the production department where specialization and division of labor have been carried to great lengths has been repeatedly stressed in this study and needs no further elaboration here. The problem of synchronization is perhaps the chief concern of the production-planning department in an intermittent process type of industry. In such an industry this department must ordinarily shoulder much of the responsibility for lack of co-ordination

in manufacturing operations unless it can be shown that the failure has been caused by emergencies which could not have been foreseen. Reports dealing with the progress of manufacturing operations and the analysis of production delays are useful chiefly in presenting this aspect of time relationships to management.[1]

Time measurements of the second type which pertain to individual operations include all reports setting forth actual operating times in comparison with standard times, analysis of overtime wage payments, and inventory turnover computations.[2]

Performance in Relation to Potential Capacities.—Many of the most important problems of the production manager arise from the necessity for making the best possible utilization of the potential capacity of his plant and organization. Expenditures must be made in anticipation of production. A plant must usually be built and equipped before production begins. A labor force, also, often must be recruited and trained at considerable expense. These constitute a relatively fixed charge upon the industry and contribute to its costs of production. Correct accounting requires that such investments shall be amortized during their useful life regardless of the rate of production during that period. This potential capacity must be paid for whether it is utilized or not; hence the relation between actual achievements and potential capacity often becomes a very significant measure of performance. All reports dealing with the analysis of idle time, either of workers or machines, are important chiefly because they throw some light upon this relationship. Indices of labor efficiency, including reports on absenteeism, labor turnover, health and accident reports, also come within this general category of measuring-devices. From the point of view of the production manager at least, their chief significance lies in their ability to reflect failures to utilize fully the current investment in labor resources.[3]

[1] Often such facts are presented in graphical form by means of the Gantt Chart, to which reference was made in chap. xv.

[2] While always stated in terms of time, inventory turnover ratios may readily be expressed in two different ways. An annual turnover of 6, for example, is merely another way of saying that the average time the material in question must be carried is two months. The latter method of expression is particularly useful in setting forth the rate of turnover of goods in process. In that case it, of course, represents the average length of the production period, which is a very significant fact to the production manager.

[3] Such reports are also useful to the personnel department, of course, in formulating and directing the personnel policies of the organization.

Performance in Relation to Cost.—Perhaps the most highly regarded and useful measures of performance which production executives possess are those pertaining to performance in relation to cost or the amount of effort expended. By "cost" is meant merely the quantitative expression of the several factors which have contributed, directly or indirectly, to a given result. These facts may be presented either in purely physical terms, such as the units of labor or quantity of material used per unit of product, or in monetary units.

Because of the universality of this method of measuring performance and the many problems of cost-accounting theory to which its use gives rise, the remainder of this chapter will be devoted to its discussion.

Physical Measures of Cost.—Owing to the difficulty of selecting a physical unit of measurement which may be applied to different factors of production, physical measures can seldom be used to show the total cost of a unit of product. The labor-hours, machine or plant hours, pounds of raw material, or units of power required to produce one unit of output may readily be computed. There is no single physical unit which will express all of these factors in combination. Nevertheless, operating ratios such as those just mentioned which represent partial costs are of considerable significance. They constitute an effective means for presenting facts since no corrections need be made for possible fluctuations in the unit itself, as is likely to be the case when costs are expressed in financial units. Furthermore, the fact that they can be used to express partial costs only is not a serious objection, especially in industries where one or more factors are of exceptional importance. In the packing industry, for example, the "yield" is regarded as highly significant. This is nothing more than the ratio (expressed in percentages) between the weight of the raw material and that of the finished product, in other words—the material cost expressed in physical terms. The special weight assigned to this ratio as an index of production efficiency is, of course, explained by the fact that in this industry material costs represent by far the major proportion of the cost of the finished product.

Financial Measures of Cost.—For some purposes, cost must be expressed in financial terms. One of the chief advantages of the monetary unit is that it provides a sort of common denominator by which all the factors of production in combination may be evaluated. Labor-hours, machine-hours, pounds of material, and units of power may all be

gauged by this common measure. The total cost of a product or service may accordingly be expressed as a single unit. This, as has already been pointed out, is impossible where physical units are used. Another important advantage of this common method of expressing cost is that it enables comparison between cost and selling price. The latter is, of course, always expressed in monetary terms, and it is next to impossible to make an intelligent comparison of these two bases of valuation as applied to finished goods unless costs are expressed in the same form. Such comparisons by which probable profits are estimated, obviously exert a profound influence upon the plans and policies of the production department.

The disadvantages of this method of expressing costs arise chiefly from the fact that the financial unit is a fluctuating one. Variations in price levels introduce variations in cost over which the internal management has no control, and hence the results imperfectly reflect the efficiency of the organization. The seriousness of this defect is often strikingly portrayed by a comparison of the operating costs of two plants. The two plants might be of identical design, and the two managements of equal efficiency, and still the costs of operation might be entirely different, not because of anything the management has done or has failed to do, but simply because the plants were built at different times. Many enterprises having plants which were erected during the war period have, as is well known, found it difficult to compete with those whose plants were built under more favorable circumstances. When such factors are permitted to influence operating costs, it is clear that the cost data can be of little value for measuring the efficiency of the internal management.

Different Conceptions of Cost.—It is well to remember at the outset of this discussion that "cost" is, after all, a term of convenience. It has been defined as the sum of all the factors which contribute to a given result; but in practice, when we speak of the cost of a thing, we may or may not consciously include all of these contributing factors, depending on what will best serve our purpose. This is merely another way of saying that complete or absolute costs are not always necessary. Indeed, for some purposes partial costs may provide an even better measure of performance than total costs, if the excluded portions are not significant or would tend to bias the judgment of the user. A simple illustration will explain what is meant. Suppose, for example, that the

total cost of producing a pair of shoes is $5.00, as compared with a cost of $4.25 six months ago. This does not necessarily imply that the manufacturer is less efficient now than formerly, although in the absence of further information such a conclusion might be drawn. But if we find, upon examination, that the increased cost is caused by rising prices in the leather market and does not reflect a lowering of efficiency in the plant itself, it is at once apparent that total cost is not an accurate measure of performance. A better measure would likely be the cost of production exclusive of material cost, or—better still—the sum of the contributions made by all factors after applying corrections for these extraneous influences. By our assumptions it is readily seen that the measure which we need is not complete or absolute costs at all, but partial costs including only those factors which are significant for our purpose.

There is, of course, nothing particularly startling in this statement, for as a moment's reflection will reveal, everyone, including accounting theorists and practitioners, are continually speaking of the cost of things or services when they obviously are referring to partial rather than to total costs. Unfortunately, and accountants themselves have not been above this criticism, the fact that we habitually adapt our concept of cost to the purpose we have in mind is not always realized. The literature of accounting contains many heated discussions concerning what should be included in and what should be excluded from cost computations, where the difference of opinion obviously arose from the fact that the disputants were viewing cost from different angles.[1] In other words, they were not talking about the same things.

A comparison of a few of the conceptions of cost in common usage will make this point clear. When an individual, for instance, makes the statement that his hat cost five dollars, he probably has in mind merely the purchase price. He does not include a valuation of the time he spent in making the selection, nor even such incidental transportation charges as he may have incurred in going to and from the store, though obviously these are a part of the cost of his hat. His reason for being content with a statement of something less than complete costs is that for his purpose these incidental charges are not significant. To measure and compute them would involve more trouble than the additional accuracy would be worth, and he accordingly ignores their existence entirely.

[1] The reader who is interested in this disputed issue among accountants is referred to *Interest as a Cost*, by C. H. Scovill (Ronald Press).

The orthodox accountant, concerned, as he is, primarily with determining the gains or losses of a given enterprise, includes a much more comprehensive list of factors in his computation of costs, but he, too, deliberately excludes some contributing factors not required for his purpose. Interest on owned capital, rent on owned buildings, salaries and wages of proprietors—all clearly contributory cost factors—are excluded. The reason for this is that his point of view is essentially that of the proprietors. His chief purpose is to measure net financial income from period to period; and the items mentioned will, in any case, be returned to the proprietors as part of their share of the returns from the enterprise.

On the other hand, and herein lies the chief cause for dispute over such items among accountants, the cost accountant often adopts the point of view of the enterprise itself rather than that of the owners. He cares little how returns or losses may ultimately be distributed among creditors and proprietors. His point of view is essentially this: Given a plant and organization without regard to its ownership, what does it cost to produce the resulting finished goods? This view is essentially that of the internal management, and obviously calls for the inclusion of some items which may well be excluded for the purpose of determining the net return to ownership.

There is no real conflict among these diverse ideas of what cost should include. They represent merely different points of view and the compilation of costs for different purposes.[1] The important thing, to accountants and production managers alike, is that the purpose, rather than some abstract concept, should determine what shall be included in cost data. If these data are to be of any service in measuring the performance of the production department, they must include only those factors which have bearing on this purpose.

The Cost Unit.—The issue thus raised is in reality that of selecting significant cost units. This, as a matter of fact, is one of the chief problems of the cost accountant, for cost accounting essentially consists of classifying operating expenses and identifying them with cost units—particular services, departments, transactions or products—as circumstances require. Since the purpose for which the unit is to be used is the determining factor in defining its form and composition, our present in-

[1] J. M. Clark has given a clear exposition of this idea in his chapter entitled "Different Costs for Different Purposes" in *Studies in the Economics of Overhead Costs.*

terest relates chiefly to those types of units which reflect operating efficiency. Both departmental and product costs are peculiarly adapted for this purpose. The former, in particular, sometimes have little significance aside from this.[1] Product costs, on the other hand, are useful for other purposes, such as determining pricing and production policies; but they, too, provide a very useful measure of performance when properly conceived.

Departmental Costs.—Departmental cost accounting consists of classifying and identifying expenses with departments. In other words, the department which is first of all an administrative unit becomes in turn the cost unit. The utility of such a classification of costs is fairly obvious. Each department represents a group of activities for which certain individuals are responsible. In performing these activities, expenses necessarily are incurred. Inefficiency within the department is almost sure to result in increased expense. It follows, therefore, that the cost of operating a department should be a useful index of its performance.

This line of reasoning is subject to certain important qualifications. An executive can scarcely be held responsible for events which are caused by circumstances beyond his control. Cost variations which are not caused by his actions are not a measure of his performance. Hence care must be exercised in determining what costs shall be identified with the department, if the resulting data are to be of much value for this particular purpose.

In deciding what costs shall be so identified, the cost accountant must be guided by somewhat different considerations than those which ordinarily influence the accountant in his classification of expenses for the determination of net income. The classification of accounts, including expenses, which appears in the general ledgers of the accounting department is designed primarily to facilitate the preparation of periodical balance sheets and statements of profit and loss. In preparing the latter statement, the accountant is chiefly concerned with assigning to each period its proper share of expenses and incomes in order that the statement will show the true profits (or losses) for the period. Perplexing problems often arise in determining which period should be charged

[1] In some instances, such as in the packing industry, where the product is marketable at various stages of manufacture, departmental costs are of service in determining at what stage of manufacture the product should at a given time be sold. There are many industries, of course, where no such alternatives are presented.

with a given expense; but in deciding this issue, the accountant proceeds on the assumption that each period should be charged with all expenses (and only those) which have resulted in benefit to the operations of the period in question.

It need scarcely be pointed out that this logical basis for assigning expenses to periods does not serve equally well for the purposes of the cost accountant. The latter is faced by a somewhat similar problem of identifying expenses, but the identification in his case is with departments (or other cost units) rather than with accounting periods. If he were to adopt the same rule and charge to each department all expenses from which it received benefit, the resulting departmental cost often would not be an effective measure of performance, which, as we have seen, is the chief reason for finding such costs.

An illustration will make this clear. Suppose, for example, that it is desired to compute the cost of operating the foundry department in order to secure a measure of this department's performance. There is no question but that the foundry receives benefit from many expenditures over which it can exercise little or no control. The production manager, for example, doubtless expends some of his energies in behalf of this processing department. Were his salary and those of his immediate staff to be apportioned among all of the departments within his jurisdiction on the basis of benefits received, the foundry unquestionably should be charged with its rightful share. It is very doubtful, however, whether this should be done. The personnel of the foundry have no control over this item of expense. To include it in the costs of their department, even if the benefit received can be measured, which is itself very doubtful, adds nothing to the value of these costs for measuring the efficiency of the foundry personnel. An increase in the production manager's salary might conceivably result in a significant increase in foundry costs, but certainly would be no reflection upon the efficiency of that department.

Obviously, only those costs over which the personnel of a department can exercise some control have any significance for purposes of measuring its performance. If any reliance is to be placed upon this index of efficiency, the degree of control which may be exercised, rather than the benefits received, must be the criterion by which the cost accountant determines what should be included in the unit.

Product Costs.—Product costs are computed by classifying operating

expenses, or such portions of these expenses as are thought to be significant for the purpose, and identifying them with the various products which have resulted from operations. The method of accounting does not differ materially from that employed for finding departmental costs. The original expenses are the same in both cases. The basis of classification only is different. Instead of stating costs in terms of the operations of the foundry, the machine shop, the assembly department, or some other more or less arbitrarily chosen subdivision of production activities, they are stated in terms of the output of these operating departments.

This type of cost unit provides a very useful measure of production operations—often, in fact, suggesting important improvements in both products and processes. To be of greatest service such data must, of course, be analyzed in sufficient detail to indicate the relative importance of the various factors which have contributed to production.

One of the chief reasons for computing costs in terms of products is that a knowledge of product costs enables the management to trace its sources of profits. Until costs have been so analyzed, there is no way of knowing whether there is sufficient margin between cost and selling price on all products or not. A knowledge of costs may not be of much service for setting selling prices, since in a competitive market selling prices are determined by factors which are beyond the control of a single manufacturer; but it is essential before a decision can be made as to which products should be produced and which should be discontinued. The determination of the proper proportions of different products with a view to securing the maximum profit is, without doubt, one of the most important problems of management, affecting not simply the production manager but every department of the business. Without a knowledge of product costs, this problem cannot be solved.

It is necessary, however, for the executive to be aware of the limitations of cost data, and especially so when they are relied upon in determining future policies. Past costs can be duplicated in the future only when conditions remain constant. Change these conditions and costs will also change. It is not sufficient, therefore, for an executive to know what his costs have been in the past. He must also know what effect the probable changes in conditions will be likely to have upon costs in the future. Unfortunately, cost accountants often have given much more thought to determining what costs have been in past periods than

to interpreting results, or predicting the effect upon future costs of proposed changes in production methods and policies.

Methods of Product-Cost Determination.—It is important to remember that product costs are always approximations. It is virtually impossible to measure accurately all of the factors which contribute to a complex manufacturing process. The quantities of materials which have been consumed and the hours of labor which have been expended can usually be so measured; but there is no way of determining, except by approximation, what value should be placed upon other equally important contributions. What proportion of the original value of a machine, for example, has been consumed in producing a unit of product? The same question might be asked concerning the building in which the goods are produced, the truck which is used to bring materials to the machine, and even the janitor's broom which is used to sweep the factory floor. All of these and hundreds of other facilities have contributed to the result, but the value of their contributions cannot be determined except by approximation.

In some instances even material costs cannot be determined by actual measurement. What proportion, for instance, of the cost of a steer should a packing plant charge as material cost to the beef, and how much to the hide? The management might, it is true, weight these products and prorate the raw material cost on that basis. Yet little reflection is necessary to convince one that such a method would probably lead to absurd results. This is merely an illustration of the type of problem known to cost accountants as "joint costs." It is one which is encountered in practically every analytic industry. Consideration of the intricate cost theory involved in the solution of this problem is unnecessary for our present purpose.[1] It is sufficient to note that the solution, in any event, must necessarily involve an approximation rather than actual measurement of the charge for materials to be made to each product.

The fact that product costs can, at best, be nothing more than an estimate need not disturb us, however. Accuracy, even in the most careful measurements, is always relative. To attempt a more accurate measurement of costs than is justified by the purpose for which they serve is wasteful. The cost accountant must always be content with ap-

[1] For an extended discussion of the problem of "joint costs," the reader is referred to J. H. Bliss, *Management through Accounts*, chap. xxxv.

proximations whenever the added value of more accurate results would not be commensurate with the increased cost of obtaining them.

It is equally important to remember, also, that the value of a system for determining product costs is not always measured by its ability to obtain the actual costs of every operation on every product each time the product is manufactured. This faulty assumption, which is perhaps inherent in many so-called "job order" cost systems which our textbooks often describe at great length, may easily place serious limitations upon the work of the cost accountant. To attempt such a formidable task in the modern manufacturing organization is almost certain to result in the compiling of an enormous amount of useless detail without bringing to a focus the facts which are significant to management. Often the cost accountant's chief value depends upon his ability to make judicious selections. The process of sampling may be just as useful to him as it is to the statistician. Neither can hope to receive much consideration unless he is able to distinguish between essentials and nonessentials.

Significance of Cost Variations.—The utility of cost data for purposes of measuring performance depends almost altogether upon the extent to which they portray variations in cost and suggest the probable causes of these variations. Indeed, if costs never varied from the accepted standard, there would be little point to cost accounting. Under such fanciful conditions the cost accountant would have nothing more to contribute when once the cost of producing a given unit of output had been determined. The significance of his labors is measured by his ability to detect variations and present his data in a form which makes it possible to determine the causes of these changes.

Many things may cause fluctuations in the cost of production. Owing to the fact that a considerable portion of the expenses of operating a plant, including such important items as depreciation, interest on investment, rent and insurance, are relatively fixed and continue regardless of the rate of output, it is at once evident that variations in this rate will cause inverse fluctuations in the unit cost of output. Suppose, for example, that these fixed costs in a given plant amount to $12,000, whereas the costs of all other materials and services required for producing one unit of finished goods are $10.00. If 1,000 units were produced, the total cost per unit would be:

Direct or variable cost per unit..............	$10.00
Fixed or non-variable cost per unit...........	12.00
Total cost per unit.....................	$22.00

If, however, 1,200 units were to be produced, all other factors remaining constant, the unit cost would be:

Direct or variable cost per unit..............	$10.00
Fixed or non-variable cost per unit...........	10.00
Total cost per unit.....................	$20.00

Unit costs have apparently declined due to no other reason than that output has increased.

Another common reason for cost variation, already mentioned, is the variability of the unit of value by which costs are measured. A general rise in price levels is, of course, certain to be reflected in rising costs. Owing, however, to the fact that expenditures do not always at once become charges to production, the relation between cause and effect can sometimes be traced only with great difficulty. A sudden increase in the price of raw materials or labor may be followed almost immediately by an increase in the cost of production, since both these factors ordinarily are acquired only as needed. This is not true of fixed assets. A machine which is purchased during a period of high prices will, through a high depreciation rate—as depreciation is ordinarily computed—tend to produce high costs during its entire life. Costs of production thus are influenced not only by the current price level but also by the price levels which existed at the time when the fixed assets which compose the plant were acquired.

Neither fluctuating prices nor variations in output can be controlled by the manager of production. It follows, therefore, that in so far as either of these factors is responsible for cost variations, the costs of production do not measure the efficiency of the production department. It is not the price paid for materials and labor but the manner in which these are utilized after purchase which is the true index of performance. If cost data are to be of service for this purpose, variations which are caused by purely external conditions must be excluded on the grounds of irrelevancy. That this seldom is done is probably due not so much to the hopelessness of the task as to the not infrequent failure of cost accountants to appreciate fully the needs of management.

Average versus Differential Costs.—An interesting aspect of variations in unit cost which is of great practical significance is suggested by the distinction between "average" and "differential" costs. Average cost is obtained by dividing the total costs incurred by the number of units produced. This is the form in which unit costs usually are presented by the cost accountant. Differential cost is the additional cost (above that already incurred) of producing additional units. This distinction is illustrated in the following example:

Number of Units Produced	Total Cost	Average Cost per Unit	Total Increment in Costs on Account of Producing Additional Units	Differential* Cost of Each of the Additional Units
100	500	$5.00	....	....
200	800	4.00	300	3.00
300	1,050	3.50	250	2.50
400	1,200	3.00	150	1.50

* Strictly speaking, of course, this is the *average differential cost of each of the additional units*, for in theory, at least, the differential cost of each unit within a given group would differ from that of every other unit in the group.

This schedule illustrates a fact which has already been mentioned, namely, the average cost per unit decreases as the number of units produced increases. The average cost of producing 400 units is $3.00. Yet the additional cost of producing the last 100 units is only $1.50 per unit.

Assuming that all units are to be sold at the same price and in the same market, this distinction may not be of much moment. On the other hand, if it were possible to sell only the first 300 units for more than the average cost of producing them, additional units might profitably be sold at any price in excess of their "differential cost," which is $1.50 per unit. It is this line of reasoning which very properly induces manufacturers who are unable to sell the entire output at a price which exceeds the average cost of production to offer their surplus stocks in some distant market, or under some special brand in the same market, at a lower price.

The concept of differential costs thus is of considerable importance in planning production and determining marketing policies. It has less bearing upon the measurement of performance, since the declining cost of additional units chiefly is caused not by increased efficiency of the production personnel but by the peculiar nature of overhead costs.

The Costs of Not Producing.—In the foregoing discussion it has been suggested that, if costs are to be used as a measure of performance, we must be careful in choosing our cost unit. The performance of an individual or a department is measured only by factors over which control can be exercised. If cost data are to be used for this purpose, irrelevant factors must be excluded from our computations.

One thing further is needful. Even the elements of cost which are significant for our purpose must be analyzed and presented in a form which makes it possible to differentiate between the costs which have been productive and those which have been non-productive.[1] As Richard Lansburgh has said, "reports on the cost of not producing are quite as important as reports on the cost of production."[2]

By this is meant, not simply what it would have cost had more goods been produced, but how much it should have cost to secure what was actually produced. The former consideration is of importance to the executive who formulates the plans and policies of the enterprise. The latter is of still greater concern to everyone who shares the responsibility for executing the program which has been adopted. It is by suggesting means of improvement that cost accounting has become the indispensable ally of production management.

[1] The terms "productive" and "non-productive" are not here used in the sense in which they have sometimes erroneously been used in cost-accounting literature instead of "direct" and "indirect." By "non-productive," as here used, is meant those costs which were actually incurred but which might have been avoided by efficient supervision.

[2] R. Lansburgh, *Industrial Management*, p. 478.

APPENDIX

BIBLIOGRAPHY, QUESTIONS, AND EXERCISES FOR FURTHER STUDY IN CONNECTION WITH THE FOREGOING CHAPTERS

BIBLIOGRAPHY, QUESTIONS, AND EXERCISE FOR USE IN CONNECTION WITH CHAPTER I

SUGGESTED READINGS FOR FURTHER STUDY

ALFORD, L. P. *The Laws of Management as Applied to Manufacturing* (Ronald Press, 1928).

CLARK, J. M. *Studies in the Economics of Overhead Costs* (University of Chicago Press, 1923), chap. vi.

CLARK, V. S. *History of Manufactures in the United States* (McGraw-Hill, 1929), Vol. I, chaps. xvi and xvii; Vol. III, chap. xxii.

DAVIS, R. C. *Principles of Factory Organization and Management* (Harper & Bros., 1928), chap. i.

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TAYLOR, F. W. *Scientific Management* (Harper & Bros., 1911).

———. "Shop Management," *Transactions of the American Society of Mechanical Engineers*, Vol. XXIV (1903) (also, Harper & Bros., 1919).

TAYLOR SOCIETY. *Scientific Management in American Industry* (H. S. Person, editor; Harper & Bros., 1929).

THOMAS, W., AND DAY, E. E. *Census Monograph No. VIII, The Growth of Manufactures 1897–1923.*

THORP, W. L. *Integration of Industrial Enterprises,* Census Monograph No. III (1924).

QUESTIONS FOR CLASS DISCUSSION

1. In comparing the typical business unit engaged in manufacturing today with the typical unit of a century ago what important differences do you discover? Enumerate technological factors which you think have in a measure been responsible for these changes.

2. Is "personality" or "method" most important as a factor in efficient production management? Would your answer be different for any of the other functional

divisions of business management? Is personality less important in business management than a century ago?

3. Distinguish between "science of management" and "scientific management." Is there a science of management? Can there ever be? Discuss.

4. From your acquaintance with the literature of scientific management, what do you find are the chief features which distinguish it from "unscientific" management?

5. Consider a small plant, such as a job printing shop for example. What would be involved in a separation of planning and performance in such a plant?

6. What do you understand by the term "industrial research"? Distinguish between industrial and commercial research.

7. In what types of industries would you expect to find industrial research of great importance? Of little importance? Why? Would the same hold true of commercial research?

8. What is mass production?

9. What specific *technological* economies may be gained by large-scale manufacturing operations? Use concrete illustrations in answering this question.

10. What other economies (besides those of a technological character) are there? From the standpoint of society, are all of these supposed economies necessarily beneficial? Be specific.

11. It has been said that large mechanical units promote economy where the capacity of the machine is a function of its cubical displacement or volume, but not where capacity is a function of speed of operation. Explain, giving concrete illustrations. Does this statement account for the large mechanical units which are typical of a large newspaper-printing plant? Explain.

12. What have been or are the most important factors in increasing the output of machines where speed of operation is the ruling consideration?

13. Specifically, what are the economies to be derived from division of labor such as is found in a large meat-packing plant, for example?

14. What is meant by "interchangeability of parts"? Of what significance is the application of this principle (*a*) from the standpoint of the manufacturer, (*b*) from that of the consumer, and (*c*) from that of the organization of industry as a whole?

15. What is a "transfer of skill" machine? Do not all machines embody this principle? Why the increased significance of this principle under modern conditions?

16. A leading scientist and industrialist, when interviewed recently concerning what he thought would be the most significant future developments in industry, stated, as reported in the press, that the principle of the Jacquard loom was the one great reserve principle which would be utilized in the industry of the future. Explain and discuss.

17. "Specialization has presented a new problem to management, namely, the necessity for securing co-ordination." Discuss, citing evidence to prove or disprove this statement.

18. In what sense is "budgetary control" a co-ordinating device? The modern "personnel department"?

19. Would an organization chart and manual aid in securing co-ordination? How?

EXERCISE I

Select some industrial merger which has been effected within recent years, and in a paper of approximately 2,000 words state what you conceive to be the chief arguments for or against the consolidation from the standpoint of increased operating efficiency.

BIBLIOGRAPHY, QUESTIONS, AND EXERCISE FOR USE IN CONNECTION WITH CHAPTER II

SUGGESTED READINGS FOR FURTHER STUDY

DUNCAN, J. C. *Principles of Industrial Management* (Appleton, 1911), chaps. vii, viii, and ix.

DUTTON, H. P. *Factory Management* (Macmillan, 1924), chaps. i and iv.

LANSBURGH, R. H. *Industrial Management* (Wiley & Sons, 1923), chaps. xxxviii–xlii.

WALKER, P. F. *Management Engineering* (McGraw-Hill, 1924), chaps. i and ii.

In this chapter it was suggested that the lot of the industrial worker, as well as the problems and methods of management, has been profoundly influenced by modern tendencies in industry. Many writings of a popular or semi-popular nature have dealt with this phase of industry in recent years. In this connection the student will find the following bibliography of interest:

CHASE, S. *Men and Machines* (Macmillan, 1929).

DUBREUIL, H. *Robots or Men?* (Harper & Bros., 1930).

O'BRIEN, E. J. *The Dance of Machines* (Macaulay & Co., 1929).

POUND, A. *Iron Man in Industry* (Atlantic Monthly Press, 1922).

BRITISH INDUSTRIAL COMMISSION. *Report on American Industrial Progress* (1927).

QUESTIONS FOR CLASS DISCUSSION

1. Some writers suggest a threefold division of the activities of the business unit: production, sales, and finance. Defend or criticize this classification.

2. Examine the tables of contents of several standard textbooks on production management and prepare a list of the activities which, according to these authorities, should be regarded as lying within the sphere of the production manager. Do you find any activities in your list concerning which you are in doubt? State your reasons and suggest possible alternatives.

3. Define: "analytic," "synthetic," and "conditional processes." Give concrete illustrations of each type. Will any of these terms properly define an entire industry? Are there any types of manufacturing processes which are not included in this classification? Can you suggest a more satisfactory classification of processes?

4. Distinguish between continuous and intermittent operations, supplying illustrations of each type.

5. What specific advantages are to be gained by continuous-process manufacture?

6. State the conditions which you think would be necessary before an industry could be organized on a continuous basis.

7. The Y Company does a large printing business, specializing in small orders for advertising materials including booklets, dodgers, car cards, letter heads, etc.

It has succeeded in building up an attractive business by producing quality printing upon short notice.

The X Company is a newspaper-printing plant of approximately the same size which publishes a daily paper in a medium-sized western city.

What differences would you expect to find in these two plants with respect to types of equipment employed, character of employment, and organization for control of production?

8. The Wilkins Metal Company possesses a well-equipped foundry adapted for making gray-iron castings of great variety which it produces on special order for machine-tool builders, railway supply houses, and similar users. The secret of its success in the past has apparently been a very efficiently organized production-planning department. Recently the plant was purchased by a large builder of farm tractors, which produces several models all of which use the same type of motor. It is proposed to use the newly acquired plant and organization for the production of motor block castings. These will be shipped in the rough to the plant of the parent-company, where the machining and finishing will be done. The present foundry department of the latter will be used for making all other castings which it uses in making its product. What changes in the internal organization of the branch plant will this move likely entail?

9. Has the lot of the worker been improved or impaired by modern industrial methods? Consider carefully.

EXERCISE II

Write a short report (approximately 1,000 words) dealing with some industrial plant with which you are familiar, giving consideration to such matters as the following: (*a*) relative proportions of the various factors of production, (*b*) types of processes employed, (*c*) nature of operations (continuous or intermittent), and (*d*) most important problems confronting the management.

BIBLIOGRAPHY, QUESTIONS, AND EXERCISES FOR USE IN CONNECTION WITH CHAPTER III

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QUESTIONS FOR CLASS DISCUSSION

"The economic causes determining the location of an industry seem to be a network of complex, diverse elements, often in an individual case so arbitrarily, or at least incidentally, composed that . . . . it seems impossible to make any general statement for most industries concerning the places to which their factories must go or concerning the causes upon which their locations depend" (quotation from the opening chapter of Alfred Weber's *Theory of the Location of Industries*).

1. List as many of these "complex, diverse elements determining the location of an industry" as you can, illustrating each concretely.

2. In view of the foregoing statement, consider the possibility of developing a "theory of the location of industries."

3. From the point of view of the individual manufacturer confronted with such a problem, do you regard the possibility of arriving at "scientific" conclusions as entirely hopeless? Discuss.

4. A large mail-order house has decided to acquire a wallpaper plant to manufacture its requirements of this commodity. The product will be manufactured for stock and will be shipped to its warehouses located in Atlanta, Philadelphia, Chicago, Dallas, and Seattle, from which customers' orders will be filled as required. No plant suitable for its requirements is available for purchase, and you have been given the task of selecting a site for the new plant. Explain in some detail how you

would proceed, giving careful consideration to the types of information you will require, where you will look for these data, and what use you will make of them in arriving at your decision.

5. Assume you have developed an automobile accessory composed of small steel and brass parts which you are convinced will have a wide appeal to all users of low- and medium-priced cars. You expect to reach this market by mail order. The plant which you propose building will employ approximately 300 men, one-third of whom will be skilled machinists who preferably have had experience in automobile manufacture. Discuss the problems you will likely encounter in selecting a location for the plant, and explain how you propose to attack these problems.

6. Alfred Weber defines the term "locational factor" as "any advantage which is gained when an economic activity takes place at a particular point or at several points rather than elsewhere." He furthermore suggests a threefold classification of such factors as follows:

A. According to the extent to which they are influential:
   1. General—those which concern every industry.
   2. Special—those which concern only this or that industry or group of industries.
B. According to the nature of the factors themselves:
   1. Natural and technical factors—those which can be altered only by changes in natural conditions—in other words, by technical progress.
   2. Social and cultural factors—those which are the result of a certain cultural environment or particular economic or social conditions.
C. According to the nature of the influence they exercise:
   1. Those resulting in regional distribution of industries.
   2. Those resulting in points of centralization or in decentralization within the regional distribution.

Give as many illustrations of these different kinds of locational factors as you can.

7. "If transportation costs were constant, all production would go to the locations with lowest labor costs." Explain and discuss.

8. Suppose labor costs were constant and transportation rates per ton-mile were uniform. What then?

9. It has been argued by some that the development of the power resources of the United States will tend to decentralize industries. Discuss.

10. What other influences, if any, tending toward the decentralization of industry can you discover? What have been the influences tending toward centralization? Do you think these are as important as formerly? Discuss.

11. Enumerate important technological developments in the production of industrial power which have occurred during the last fifty years; and show what has been their influence, if any, upon industrial location.

12. What is a parasitic industry? A loft industry? What are the general conditions which cause these types of industries to develop?

13. Do financial considerations have an important influence upon industrial location? Is this factor more or less important than formerly? Why?

14. "It may happen that for different qualities of a product the locational fac-

tors are so similar that they are, practically speaking, equal." Under what circumstances might the quality of product one proposes to manufacture have important bearing upon the question of plant location? Cite concrete illustrations in answering this question.

15. Are the factors governing the choice of a plant site identical with those influencing its regional location? Discuss.

16. Look up the facts concerning the location and nature of operations of the various plants of each of the following companies:

1. International Harvester Company
2. Bethlehem Steel Company
3. Great Western Sugar Company
4. Commonwealth Edison Company of Chicago
5. General Motors Corporation
6. Manville-Jenckes Textile Company
7. Western Electric Company
8. Anaconda Copper Company
9. Washburn-Crosby Milling Company
10. E. I. du Pont de Nemours and Company

How do you account for the facts you have discovered with respect to the location of the various plants of these companies? Do you think that other factors (besides locational factors) have in any instance been responsible for the situation as you find it? What factors, for instance? Do you think anything would be gained by greater centralization in any of these companies?

17. In the manufacture of a certain product practically no waste or shrinkage occurs. The finished goods and the raw materials are of equal bulk; neither is perishable; and both take approximately the same transportation rates. Assuming that labor is not an important factor in the production process and, furthermore, that the source of raw materials and the market are fixed points 1,000 miles apart, where with reference to these points would you locate the plant?

What other assumptions have you implied by your answer to this question?

Specifically, what does proximity to the market mean in the case of a nationally advertised and widely used product such as Ford cars, for example?

Can the location of a manufacturer's market ever be defined in terms of a given point which remains fixed regardless of where his plant is located? Assuming that in a given case it can, does this simplify the problem of determining the most economical location for the plant?

18. Mr. A is the sole owner of one of the largest wholesale bread bakeries in Pittsburgh. He has been established for a number of years and has succeeded in building up a very profitable business in manufacturing a quality product which is marketed under a distinctive brand name. It has become necessary, for personal reasons, for A to move to Kansas City, where he expects to continue in the bakery business. Indicate the issues which A must consider in determining what to do with his present plant. Would his problem be the same if he were engaged in the manufacture of a proprietary drug product, let us say, which has been advertised on a national scale?

19. Has the consideration of the problem of plant location any place in a study of production management? Is there more justification for considering it here than there would be in a managerial course in any of the other functional fields?

20. Who, in your opinion, should be responsible for studying problems of plant location in a manufacturing business and for making decisions concerning same?

21. The center of population in continental United States has with each decade since 1790 moved westward with great regularity following closely the thirty-eighth parallel of latitude. The center of manufactures has also moved westward with considerable regularity, though on a parallel somewhat north of that drawn through the centers of population. Furthermore, the westward movement of manufactures, since 1880 at least, has been more rapid than that of the centers of population. What inferences, if any, can be drawn with respect to the relation between these two movements?

22. In the domestic beet-sugar industry there is a pronounced tendency for the extractive and refining branches of the industry to be located together near the sources of raw material. In the cane sugar industry, on the hand other, where foreign sources of raw material are in the main relied upon, the two branches of the industry are carried on at separate locations, the raw materials being imported in the form of raw sugar and the refining processes being located on the seaboard near the point of entry. How do you explain these differences in location in the beet- and cane-sugar industries, both of which compete for the same markets?

EXERCISE III—1

Prepare a map showing the approximate geographical distribution of a leading industry (not company) to be assigned by the instructor, and in a paper of approximately 1,000 words give your explanation of the probable reasons for the conditions as you find them. If, in the course of your investigation, you discover any important shifts in progress in your industry, give attention to the probable significance and causes of these changes.

EXERCISE III—2

During recent years, much has been said concerning the relative tendencies toward centralization and decentralization in industrial location. Assume you are about to undertake as a research project the determination of what has been or is actually occurring in this respect. Prepare a short brief defining the problem as you view it, outlining your proposed method or methods of attack, suggesting probable sources of useful data and indicating, as clearly as you can, the practical significance which might reasonably be attached to the facts which you hope to be able to uncover by your proposed study.

BIBLIOGRAPHY, QUESTIONS, AND EXERCISES FOR USE IN CONNECTION WITH CHAPTER IV

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QUESTIONS FOR CLASS DISCUSSION

1. Cite examples of industrial plants with which you are somewhat familiar which bear evidence of the relation between plant layout and operating efficiency. Can you cite examples of industries where this relationship does not appear to be important?

2. Under what circumstances is plant layout an important consideration?

3. What are the most important factors to be considered in laying out an industrial plant? Why important?

4. List the various general types of factory-building construction you have observed, and state the conditions under which each would likely be used.

5. The factors affecting the type of building are said to be:

a) Visual control of activities,
b) Economy in the movement of materials,
c) The value of land,
d) The nature of the industry,
e) The nature of the processes,
f) Permanence and resale value.

Explain each of these factors and cite instances where you think each has been an important consideration.

6. According to a recent report of the Boston Manufacturers Mutual Fire Insurance Company, fire insurance rates on factory buildings have declined more than 90 per cent since 1880. Mention factors which you think have probably been most important in effecting this saving in factory operation costs.

7. What do you understand by the term "direct-line production"? Give illustrations of the application of this principle, indicating the gains which have thus been realized.

8. It has been said that there are only two possible methods of arranging production processes: (*a*) to bring the materials and the workman to the machine which is fixed and thus determines the work place, or (*b*) to bring the workman and the machine to the materials. Cite examples of both these methods. Can you think of any instance where the workman is the fixed element?

9. Discuss the effect of power-transmission developments of recent years upon plant layout.

10. State the conditions which you think would be necessary for satisfactory illumination.

11. Contrast the problem of layout in a continuous-process plant with that in one of intermittent-process type.

EXERCISE IV—1

The Williams Box Company has outgrown its present leased quarters and the management has decided to build a new plant which will permit needed expansion and provide a better layout of its equipment than is possible in the present building, which was not originally designed for this type of manufacture.

This company manufactures corrugated and fiber-board boxes. The corrugated boxes are all of one-piece construction, each being cut from a sheet of corrugated board which has been scored at the proper places to permit the folding of the stock to form the box. The box is in each case held together by a pasted cloth tape which joins the two ends of the board to form one corner of the box. These boxes are made in a wide variety of sizes to suit the individual needs of the customer and are manufactured always to special order. In many cases, though not always, the purchaser's name and other advertising matter is printed upon one or more sides of the box.

The fiber boxes are all of one size and design and are supplied in large quantities

for use as shipping containers to the shoe-manufacturing trade. These boxes are of three parts, including the body and two ends or headers. The body of the box is made of a piece of fiber board 3×9 feet in size, which is scored transversely at four points to facilitate folding and is then stitched on a wire stitcher to form an open-end box which may be folded flat for shipment. The ends or headers are cut and scored for fitting the box but are shipped separately and are stitched to the box by the purchaser in his own plant.

The raw material from which all corrugated boxes are made is heavy brown paper stock which is received by the plant in large rolls weighing approximately 2,000 pounds each. Three rolls of this paper are placed upon spindles at one end of the corrugating machine, and the three sheets are inserted in the rollers of the machine which are designed in such a manner that the central sheet is corrugated and glued at top and bottom to the other two sheets thereby forming the corrugated board. This board is automatically cut into sheets 6×10 feet in size and placed upon skids in piles 6 feet high at the other end of the machine.

Two such machines are required, each occupying a space 15 feet wide and 50 feet long. In addition a boiler is required for generating steam used in the corrugating process. The boiler occupies 600 square feet of floor space. The glue is prepared in a mixer requiring 100 square feet of floor space, and is pumped to a tank on the floor above the corrugating machine, to which it is fed by gravity. This tank is 10×10 feet in size. In order to save heat, it is desirable to have the boiler-room and the mixer as near the corrugating machines as practicable. These must, however, be placed either in a separate building or in a separate room with fire-wall protection.

After the completion of the corrugated board it is allowed to season on the skids for several days, and 2,000 square feet of storage space must be allowed for this process.

From storage the board is first moved to the slitter, which is equipped with a series of rapidly revolving knives which cut the pieces to correct size, the pieces then being moved to the No. 1 slotter, which cuts away the portions not required in making the box. The pieces are then sent to the printing press, where the printed matter is added, and thence to the scorer, where the scores to aid in folding the stock are made. The final operation is performed on the paster, where a linen tape is used to join the corners of the box. The stock is then stacked flat in bales of 100 pieces, tied with wire, and sent to storage, where they are kept until the customer calls for delivery.

The fiber boxes are made from fiber stock which comes to the plant in sheets 6 feet wide and 9 feet long, 500 sheets to a skid, which weighs approximately 4,000 pounds. This material is delivered on the skid direct to the slitter, previously mentioned, from raw materials storage. Here the stock is cut in two pieces for body sheets and in eight pieces to form the headers. Body sheets are then sent to slotter No. 2, while the head sheets are sent to slotter No. 3.

From these operations both pieces are sent to the scorers. The scoring operation completes the headers, but the body sheets must be sent to printing press No. 2 for printing and thence to the stitcher, where the edges are joined to form the body of

the box. Bodies and headers are then stacked in separate bales of 100 pieces each of which is tied with wire and sent to finished goods storage.

The space requirements in the new plant for the various machines just mentioned will be as follows:

1 slitter, 15×20 feet
2 slotters No. 1, 10×10 feet each
1 slotter No. 2, 10×12 feet
1 slotter No. 3, 6×10 feet
5 scorers, 10×10 feet each
1 printer No. 1, 8×12 feet
1 printer No. 2, 6×10 feet
3 pasters, 10×15 feet each
2 stitchers, 8×8 feet each

In arranging these machines, as well as the corrugating equipment previously mentioned, they must never be placed nearer to one another than 4 feet, and sufficient aisle space must be provided wherever needed for the moving of material skids. Such aisles must be 8 feet wide.

In addition to space for equipment, 4,000 square feet should be provided for raw-material storage, 6,000 square feet for finished goods, 100 square feet for supply storage, and 400 square feet on the manufacturing floor for space in which to bale the finished goods. Office space amounting to 1,500 square feet and men's and women's lavatories of 250 square feet each will be sufficient. Freight elevators require a space of 90 square feet and stairways 250 square feet on each floor.

Ten per cent should be deducted from outside gross area for walls and interior obstructions in the building.

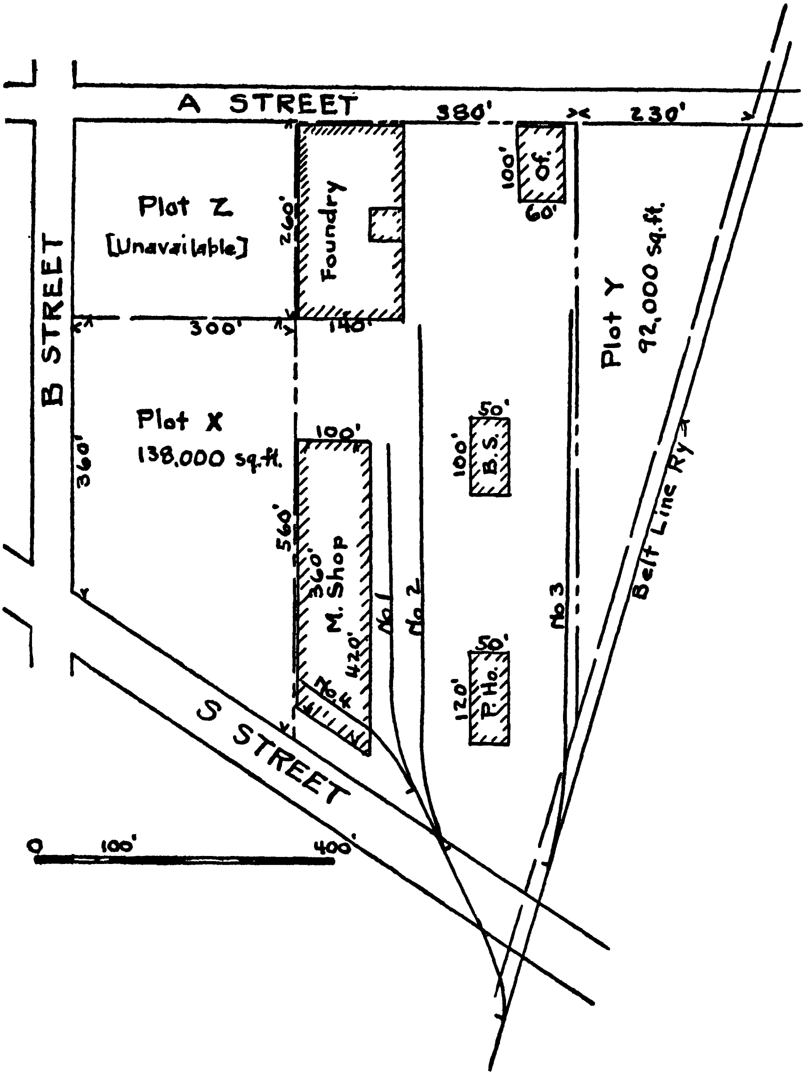
A rectangular plot 90×150 feet abutting a paved street at one end and with an industry track already in place on each side has been procured. Allowing 10 feet for the track on each side, 10,500 square feet is available for building purposes.

Prepare floor plans for a reinforced concrete and brick building to house the plant, showing the location of all machines and facilities which you think will give the best possible layout. Since none of the present machines are worked to capacity, it is felt by the management that no further space need be allowed for future expansion, provided the new plant is adequately laid out in the first place.

EXERCISE IV—2

The Bradshaw Machine Company was founded in 1854 for the purpose of manufacturing steam engines. Since that time, power-house equipment has undergone profound changes; and this company, which has always had the benefit of progressive management, has become one of the leading manufacturers of steam and hydraulic turbines. Its line of products has also expanded with the passing years, and now includes other types of power-house and plant equipment: pumps, compressors, and centrifugal machinery such as is extensively employed in chemical works and sugar refineries. Technical improvements in the design of centrifugal pumps, as well as the demand for pumping machinery of enormous capacity, have in recent years caused this type of pump practically to displace those of older design for most industrial uses, and the pump branch of the business has accordingly advanced

very rapidly. In all lines the tendency has been to develop standard models of numerous kinds, which are manufactured for stock and are delivered to the purchaser as soon as ordered. In the last twenty years, however, an ever increasing



proportion of the business in all lines has been the building of large special installations, which are always manufactured to order. From a production point of view, it has been deemed desirable to separate these two lines of production; and since expansion in the present plant is not feasible, it has been decided to acquire a new

plant to which will be transferred the manufacture of standard built products. The present plant will then be used exclusively for the building of large special installations.

In looking about for a plant which may be adapted to the company's requirements, that of the Railway Foundry and Supply Company has been acquired. This plant is as shown in the accompanying diagram, and consists of a foundry building 140×260 feet; a machine shop and assembly building, 100×380 feet; a blacksmith shop, 50×100 feet; an office, 60×100 feet; and a power-house 50×120 feet, all situated on a plot containing approximately 8.05 acres and including 4 industry tracks, as shown, with a total storage capacity of 35 cars.

The foundry building, including the cupola, is of modern steel one-story construction with monitor-type roof. It may with little alteration be adapted to the needs of the Bradshaw Company. The machine shop is also a modern and well-built one-story brick structure with saw-tooth roof. This building may be used either as a machine shop or as a storage and shipping department. The blacksmith shop is old and unfit for use and will be torn down. The power-house also is obsolete; and since the new company will purchase its power from the local power company, this building will be no longer required. The office is a one-story frame structure; and since it is desired to place the office facing upon S. Street, which has recently been opened, the present office has been sold and is being dismantled.

In order to provide room for expansion, options have been taken on Plots "X" and "Y" and will be exercised if these areas are needed to give a satisfactory layout. Plot "Z" is already occupied and cannot be purchased.

The manufacturing processes which will be employed in the reconditioned plant include the making of a wide variety of castings in the foundry. Scrap steel and pig iron in varying proportions are used as raw material in this department. When the castings have cooled, they are cleaned and then stored in the open for one or two months for the purpose of weathering. Cores are used in making many of these castings; and hence a core department, as well as facilities for pattern and sand storage, must be provided adjoining the foundry floor. After weathering, the castings are taken to the machine-shop, where machining operations are performed.

All moving parts are forgings which are roughly fashioned in the forge shop from bar and plate steel stock. Forgings also must be machined and then all parts are assembled and stored until shipment in the storage department. Bronze bearings and brass fittings are required but are purchased in finished form from outside parties, as are the electric motors, which are provided with many installations. Provisions for unloading and storing these parts near the assembling department must be made.

Building requirements have been analyzed, and it has been decided that the following additional space is essential:

Foundry—including one additional cupola which will be placed adjoining the present one, core making department, pattern storage, and additional space for casting and cleaning equipment—30,000 square feet.

Storage building for core and foundry sand—5,000 square feet.

Forge shop—25,000 square feet.

Machine shop (total requirements)—36,000 square feet.
Assembly and paint shop—20,000 square feet.
Office—15,000 square feet.

It is planned to use the present machine-shop building for a storage and shipping department. Eight thousand square feet in the south end of this building, together with the service track, will be used for storing purchased finished parts and supplies. The remainder of this building will be used for storing finished machines, boxing for shipment, loading, etc.

For the office it has been decided that a modern two-story brick structure of pleasing design shall be built facing on S. Street.

All other buildings and additions will be built to conform with the construction of the existing plant.

Storage yard space will be required as follows:

Foundry raw materials—50,000 square feet.
Forge shop materials—20,000 square feet.
Casting storage—25,000 square feet.

The first two of these yards will be served by gantry cranes, while a tractor and trailers will be used in the third. Each of the raw-material storage yards and the shipping dock must be supplied by separate track facilities. While desirable to use as much of the present trackage as possible, this is not essential if a more efficient layout can be arranged otherwise. The storage space required (allow 40 track-feet per car) on the various tracks is as follows:

Purchased-parts storage—3 cars.
Foundry-materials yard track—10 cars.
Forge-materials track—5 cars.
Shipping department—12 cars (this may be arranged in two tracks with loading dock between if a better arrangement is thus secured).

Required: Prepare a layout diagram for this plant, giving careful attention to all such matters as direct-line production, economy of internal transport, accessibility both from the standpoint of entrance and exit. In specifying space requirements, ample provision has been made for expansion, and this aspect of the problem may accordingly be ignored.

EXERCISE IV—3

The Wilson Shoe Company, manufacturers of high-grade shoes, has decided to build a new plant. A site 110×150 feet at the intersection of two important streets has been chosen, and tentative plans have been prepared for a modern reinforced concrete and brick building. The structure as planned is to be L-shaped, 50×150 feet with a wing 60×70 feet. There are to be eight floors, including the basement, and the building is to be equipped with two combined freight and passenger elevators each requiring 100 square feet of floor space. The stair wells will require 250 square feet additional space, and it is proposed to provide locker and wash-rooms requiring 400 square feet on each floor. The new plant, it is expected, will have a capacity of about five thousand pairs of shoes per day and will employ from 900 to 1,000 workers.

The manufacture of shoes is a somewhat involved and highly organized process. Orders are received by the planning department, where production orders and material requisitions are prepared. The latter are sent to the leather-storage rooms, directing that the required stock be sent to the cutting departments. The production order is also sent to the cutting-room and from that point accompanies the lot throughout the manufacturing process until the packing-room is reached. Each sales order under normal conditions constitutes a separate production order, which is carried through the plant independent of other orders.

Soles are cut from sides of sole leather by means of a "dieing-out" machine consisting of a press which forces dies of the approximate size of the finished sole through the leather. These rough-cut soles are soaked in large vats of lukewarm water for 24 hours and then removed, put on racks in a heated room and dried. The dried soles are then passed through a series of rollers under great pressure. This compresses the fibers and improves the wearing qualities of the leather. Finally the sole is run through a slitting machine which reduces the stock to an even thickness. This operation completes the rough soles, which are held in this department until required by the sole-laying department.

Insoles are purchased ready-made from findings manufacturers, and their production need not be considered.

Upper leather of the required kind is sent from the storeroom to the cutting-room. All cutting, or nearly all, is done by hand by skilled cutters, who spread the skin upon a bench and cut piece by piece with a sharp knife, being guided as to shape and size of pieces by brass-bound patterns made of fiber board. Each order is cut by a single cutter, who enters his number on the order when it is completed so that any faulty workmanship which may later be discovered can be traced to him. From the cutter the various parts are passed to girls who operate the "pinking" machines, which skive or bevel the edges of the leather to an even thickness. The pieces are then sent to other girls, who bind or "top-face" the edges wherever necessary by turning down the beveled edges and gluing them firmly in place. This operation also is largely a hand operation performed at a bench. All parts of the uppers are then marked or die-stamped on the under edge with the number of the order for purposes of identification; and if any perforations or other special decorations are specified, these are added at this point by girls on perforating machines. Each order is then assembled, tied in a single bundle and sent to the sewing department.

The patterns which are used by the cutters are made from fiber board, there being a separate pattern for each part of each style and size of shoe. Patterns are cut by means of an ingenious pantograph machine which is controlled by a master pattern of size 7 which has been prepared from the drawings of the designing department. By a simple adjustment of the machine any size from 4 to 14 can be cut from the master pattern. The patterns are then bound with brass and are stored in racks in the cutting-room, where order boys match them up with the production orders and deliver them to the cutters.

Shoe linings are cut by means of dies from canvas stock and are held in the lining department until requisitioned, at which time they are delivered to the sewing-room.

In the sewing-room, machines are placed in long rows or batteries, each two rows being placed back to back in pairs. All sewing-machines are power driven, of course, and are operated by women. Each operator is assigned a certain operation for a specific order and the materials are passed from worker to worker until upper leather and linings are completely assembled. The uppers are then sent to the eyelet machines, where eyelets are quickly cut and set, and thence to the lacing-machine, where each upper is laced securely by means of a stout twine. All uppers included in the same order are then placed together on a wire hook and are ready for lasting.

In the lasting department the lasts are stored. These consist of a hardwood form or "last" around which each shoe is built. Sufficient lasts of the proper sizes for the order are taken from the storage bins and placed upon racks. These racks are approximately 1 foot wide and 5 feet long, consisting of several shelves and equipped with rollers to facilitate moving. Each rack is capable of carrying from 2 to 3 dozen pairs of shoes, and an order, after being assigned to a rack, is left on it until the shoes are completed.

Upon receiving the bundle of uppers from the lacing-machine, the toe boxings are slipped into place and the counters are inserted. A boy puts paste on the counters and then hands them to another man, who sticks them one by one in the uppers he has received. The uppers are now ready for the lasts, which are inserted and held in place by a tack driven through the back of the upper into the last to which the insole has previously been nailed.

The lasted uppers are then placed on the rack again, and it is sent to the pull-over machine. Before placing the shoe in this machine, the toe is steamed for a few seconds. The shoe is then placed in the machine, which performs a very important operation. The uppers have been cut to conform exactly to the shape of the last, and must now be fitted carefully to make a well-built shoe. The pincers of the machine grasp the leather at different points on both sides of the toe and draw the leather securely against the wood of the last, and at the same time tacks are driven on each side and at the toe which hold the upper securely in position.

The shoe is now sent to the lasting-machine, which performs what is probably the most important operation in shoemaking. The upper is pulled securely at all points so as to snugly fit the last. Hand fitting is resorted to wherever necessary, and the upper is tacked to the last on all sides except the toe, which is fitted in the next operation which is performed on the "stapler." This operation consists of drawing the toe tightly and binding it with a wire called a "staple," which is fastened to a tack on each side about ½ inch back of the tip of the shoe. The operator now takes the shoe out of the stapler and places it in another which trims the surplus leather away from the toe. The next operation removes some of the tacks from the last, thus preparing the shoe for the welt.

The welt is a narrow strip of leather that is sewed along the edge of the shoe beginning at the front of the heel and ending at the same place on the opposite side of the sole. The welt is sewed to a lip which has previously been cut upon the insole, and the needle passes through the lip, the upper, and the welt, uniting all se-

curely and allowing the welt to extend out evenly around the edge of the sole. The work is done on a welt-sewing machine. Strong linen thread is used, and the stitches are drawn tightly, the machine feeding both the welt and the thread as it proceeds.

The shoe is then sent to the inseam-trimming machine, where surplus portions of the lip, upper, and welt are trimmed off, after which the operator beats the welt down smoothly with a hammer. The tacks in the insole are now withdrawn on another machine, the unevenness of the sole is filled by applying a layer of asphaltic material, and the shoe is ready for placing the outer sole.

The outsole is placed on a sole-laying machine. In this machine there is a mold which conforms approximately with the curve of the sole. The sole is placed in the machine, cement is applied, and the last is placed in proper position above it. Pressure is applied, and the sole is securely glued to the insole. The surplus portions at the edge of the sole are now cut away on a Goodyear rough rounding machine, which leaves the soles of all shoes of the same size exactly alike.

The next operation cuts a channel on the outer side of the sole in preparation for sewing to the welt. The sewing is performed on a Goodyear lockstitch machine, which is similar to the welt-sewing machine. A thoroughly waxed thread is used, and the stitching is drawn so tightly that it holds the sole and welt securely together even after the outer stitches have worn away. After the stitching, glue is applied by hand to the channel lip, and the shoe is then inserted in a Goodyear channel-laying machine, which presses the lip back in place thus hiding the stitches on the bottom of the sole.

After the sole has been sewed on, the next operation is that of leveling. This is done on an automatic sole-leveling machine. The last is held securely on a spindle, and rollers are passed over the upturned sole under heavy pressure. This levels the sole and removes all unevenness from the bottom of the shoe. This practically completes the shoe, but it must next be thoroughly dried, which is done in a drying-room where heated air is circulated by revolving fans. From the drying-room, where it is kept for a number of hours, the shoe is sent to the heeling machines. Here the heel is put in place and securely nailed by automatic nailing machines.

Following this process, the heel is shaped and the edge of the entire sole is beveled and finished. It is then burnished on a "burnisher," and the sole is sanded smooth on rapidly revolving sanding wheels. The soles are then painted and are ready to receive their final polishing. Before polishing, the lasts are finally withdrawn and returned to the last-storage department. The "vamp" is creased over the ball of the foot so that when the shoe is bent in walking the crease will always be even. The finishing is done by hand by girl operators, and the final polishing is performed on polishing wheels.

The shoes are finally inspected, and trade-marks are inserted in the heel and stamped on the outer sole. Laces are put in, and the shoes are put in boxes and stored in the finished stock room. When ready to be shipped, they are packed in fiber boxes, securely fastened, and sent to the shipping-room.

In making a study of these processes with a view to determining the space re-

quirements for the various departments in the new Wilson plant, the following data have been compiled:

		Square Feet
A. Manufacturing service departments:		
Leather storage		4,200
Finished-goods storage		4,000
Shipping		2,000
Receiving		1,000
Mill supply and repair shop		2,000
Supplies and findings storage		1,000
Boiler-room		5,000
B. Employee services (exclusive of lavatory and locker rooms already mentioned):		
Restrooms—men		600
Restrooms—women		1,000
Medical dispensary		800
Cafeteria and kitchen		7,500
C. Offices:		
General and factory office		5,500
Salesmen's rooms		1,000
Designing		1,100
D. Factory space:		
Outsole cutting and treating		4,000
Lining cutting and storage		700
Cutting department:	Square Feet	
25 cutting benches 4×6 feet each	1,000	
Pinking, perforating, binding, and marking—4 benches 4×40 feet	1,760	
Stock benches and racks	500	
Pattern-making	400	
Pattern storage	320	
		3,980
Sewing department:		
Sewing benches, 8 batteries, 6×40 feet including aisles	4,480	
Eyelet and lacing machines	500	
Order matching and storage	500	
		5,480
Lasting department:		
Last storage	3,000	
Pullover machines, 10, 5×10 feet	500	
Lasting machines, 10, 7×7 feet	500	
Upper trimming machines, 10, 5×5 feet	250	
Rack storage, 300, 1×5 feet	1,500	
		5,750
Welting department:		
Welting machines, 10, 8×10 feet	800	
Welt-laying machines	100	
Sole-filling benches	100	
Rack storage, 200	1,000	
		2,000

Sole-laying department:		
Laying machine, 4, 5×10 feet	200	
Rough rounding machines, 10, 8×8 feet	640	
Sole-sewing machines, 10, 10×10 feet	1,000	
Channel-laying machine	200	
Sole-leveling machine	400	
Rack storage, 500	2,500	
		4,940
Drying department		3,000
Heeling department:		
Tackers, 10, 10×10 feet	1,000	
Trimming machines	700	
Rack storage, 100	500	
		2,200
Sole-finishing department:		
Scouring	500	
Sand dressing	500	
Painting	200	
Burnishing	400	
Rack storage, 200	1,000	
		2,600
Treeing department:		
Ironing machines	200	
Last storage	200	
Vamp-creasing machine	100	
Polishing machines	1,000	
		1,500
Inspection		500
Trade-marking		500
Packing department		2,000
Boxing and box-making		1,000
Total		76,850

Required: Prepare sketches showing how you would lay out this plant. It should be borne in mind that a satisfactory layout must not only provide for processing with minimum movement of materials but must also make the best possible utilization of natural lighting.

BIBLIOGRAPHY, QUESTIONS, AND EXERCISES FOR USE IN CONNECTION WITH CHAPTER V

SUGGESTED READINGS FOR FURTHER STUDY

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SHEPHARD, J. A., and HAGEMANN, G. E. "Report on Formulae for Computing the Economics of Material Handling Equipment," *Transactions of the American Society of Mechanical Engineers*, Vol. XLVII (1925).

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QUESTIONS FOR CLASS DISCUSSION

1. "Fundamentally, it may be assumed that every plant is built around inter-departmental transportation." Discuss. Do you think this is necessarily true of all types of plants?

2. Manufacturers of materials-handling equipment have been very insistent in their claims that much waste in industry is the result of obsolete and inadequate methods of handling materials. What specific types of industrial waste may possibly be traced to this source?

3. Referring to the classification of handling devices suggested in the chapter, give concrete illustrations of the use of each of these types of equipment.

4. Under what conditions do you think the use of hand trucks would be justifiable? Assume that a given materials-handling job is being performed in this manner in a factory where you are manager and you are considering the advisability of using power trucks instead. How would you proceed in solving such a problem? What information would you require, and what use would you make of it?

5. Discuss the relative merits of power trucking and industrial railways for use in inter-departmental transport in a heavy metal-working plant.

6. What factors must be considered when designing the railway receiving and shipping facilities of a large industrial plant?

7. Under what general conditions are overhead carriers likely to be used?

8. We have heard much in recent years concerning the advantages of the "conveyorized" plant. Why has this type of equipment been adopted so generally? Under what conditions is its use likely to prove economical?

9. Discuss the problems which are likely to arise in connection with the organization of plant transportation facilities.

10. "No matter how small a transportation system may be in a plant, there should be one man in charge, and he responsible for everything pertaining to the operation of the system and the transfer of materials, including men, trucks, paper work, and costs. To him should be relegated the duty of devising or passing upon proposed improvements in the system." Do you agree with this statement? Discuss and criticize.

11. In what type of plant would such a system be most applicable? Could you use this plan in a steel mill? a cement plant? a shoe factory? an automobile plant? Does such a system involve completely centralized control of all plant transportation? Assuming the plan is applicable in a given plant, how would you suggest that control should be exercised over other material-handling activities?

EXERCISE V—1

The plant of the Arland Machine Company includes eight departments which, for the sake of convenience, have been designated by the letters A to H, inclusive. Department A is the main storeroom for raw materials. The only other department which receives inbound shipments of raw materials is C, which is also a processing department. Department H is the finished-goods storage and shipping department. All goods are delivered to this department when the manufacturing processes are completed. The remaining departments, B to G, inclusive, are processing departments, and the products normally pass from one of these to another in approximately alphabetical order.

The plant is well laid out from the standpoint of sequence of process. Inbound shipments are separated from outbound movements, though the finished-goods shipping department (H) and the raw-materials receiving department (A) are located not far apart. The nature of the product is such that trucking provides the most satisfactory means of interdepartmental transportation. Tractors and trailers are used for this purpose. Heretofore, each department has been assigned trucking equipment and has been responsible for making all required deliveries to other departments. Two-ton electric-driven tractors, each with a crew consisting of a driver and one helper, are used, departments B and D having one each and departments A, C, E, F, and G having two each. Department H delivers no materials to other departments and consequently has no equipment employed in this service. The plan has been to leave a trailer wherever needed for loading or unloading. Whenever a trailer is to be moved, it is picked up by the tractor-driver and taken to wherever it is required.

The plant is operated in two eight-hour shifts in all departments, and it is estimated that the annual cost of this inter-departmental transportation service is:

Labor:		
24 drivers — $5.00 per day, 300 working days		$36,000
24 helpers — $3.50 per day, 300 working days		25,200
Equipment:		
Investment, 12 tractors — $3,000	$36,000	
Investment, 200 trailers — 150	30,000	
Depreciation and interest, 16 per cent of	$66,000	10,560
Operating cost, at 30 cents per tractor-hour, 16 hours — 30 cents ×12×300 working days		17,280
Total annual cost		$89,040

The production manager has felt that this service was costing too much money and has, upon several occasions, brought pressure to bear upon the foremen of the various departments to reduce this item of expense. They have insisted, however, that they cannot get along with less equipment if delays to production are to be prevented, and have argued that, if such delays were permitted to occur, the losses from that source would be greater than any savings in transportation cost which could possibly be effected.

The management is not convinced and has determined to centralize responsibility for inter-departmental transportation under a superintendent of transportation and, provided the plan is found in practice to be feasible, has decided to operate the tractors on schedule over a definite route, the tractor crew picking up and dropping trailers wherever they are required along the route.

A tentative route has been mapped out, beginning with department A and passing by way of the other departments in alphabetical order to department H, and thence to department A again, thus completing the circuit. The foremen of the several departments have been consulted and have admitted that, if a schedule can be worked out permitting the arrival and departure of trains at frequent intervals, no objection can probably be raised to the plan from the standpoint of possible delays in the movement of materials. The production manager has accordingly instructed the engineering department to investigate the problem, and they have compiled the following data:

Average daily (2 shifts of 8 hrs. each) tonnage to be moved from originating to receiving departments:

Originating Department	Receiving Departments							
	A	B	C	D	E	F	G	H
A	×	200	20	......	200	....	10	....
B	....	×	....	200	....	....	....	....
C	40	....	×	50	....	200	5	....
D	....	....	10	×	240	....	....	....
E	20	....	15	....	×	405	....	....
F	....	....	5	....	....	×	600	....
G	15	....	....	....	....	....	×	600
H	....	....	....	....	....	....	....	×

Based on these data, and assuming that all trains shall be operated in the same direction with no back hauling, the tonnage movements between departments on the various sections of the proposed route have been computed as follows:

Section of Route	Tonnage Moved
A to B	460 tons
B to C	460 tons
C to D	705 tons
D to E	705 tons
E to F	705 tons
F to G	705 tons
G to H	705 tons
H to A	105 tons

In examining the route which has been selected, it has been found that the distances and grades over which the materials must be hauled are as follows:

Section of Route	Distance in Feet	Percentage of Grade	Total Distance in Feet
A to B	500 100	0 +1	600
B to C	300	+2	300
C to D	500	0	500
D to E	100 100 200 300	−2 −3 −1 0	700
E to F	400 300	0 +2	700
F to G	400 300	+2 0	700
G to H	200 100 600	0 +2 −1	900
H to A	500	−2	500
Total			4,900

The number of crews which will be required to move this estimated tonnage of materials over the route as described, depends (*a*) upon the rate of travel, (*b*) the time consumed in stopping to pick up and drop loads, (*c*) the number of trailers hauled per train, and (*d*) the tonnage capacity per trailer.

The electric tractors now in use which will be placed on this route can be safely operated at the rate of 200 feet per minute. It is estimated that for each stop 6 minutes should be allowed if trailers must be picked up, or 3 minutes if only trailers are to be dropped. All stops will be made upon signal wherever required in the various departments, and it has been estimated that 6 pick-up stops and 4 drop stops per trip is a fair allowance of time for this purpose.

The trailers, which weigh 1,500 pounds each, have a carrying capacity of 1½ tons. The number of trailers which may safely be handled in a single train depends

upon a variety of factors, including (*a*) the grades over which the haul must be made, (*b*) the load to be carried, and (*c*) the length of train which can be handled expeditiously. The last consideration, it is estimated, will limit the train length to a tractor and 6 trailers, but the grades rather than this factor are expected to be the limiting consideration, since the load to be handled can, of course, be no greater than can be pulled over the steepest grade in the route.

In order to determine the load which can be handled over a given grade, the following formula[1] is used:

$$T.E. = 50(T+t) + 20G(T+t) + 20GW,$$

in which the symbols represent the following: $T.E.$ = tractive effort (in pounds) which must be exerted by the motive power; T = weight of load (in tons); t = weight of trailers (in tons); G = percentage of grade; W = weight of tractor (in this case, 2 tons).

The maximum tractive effort which can safely be exerted by a 2-ton tractor of this type in operation is 1,000 pounds, and care must be exercised in order that the load may not cause this limit to be exceeded at any point along the route.

Assuming these conditions as stated, and furthermore that the service is to be rendered at a fairly regular rate throughout the 16 hours which comprise the two-shift factory day, prepare a report for the production manager, giving consideration to the following points:

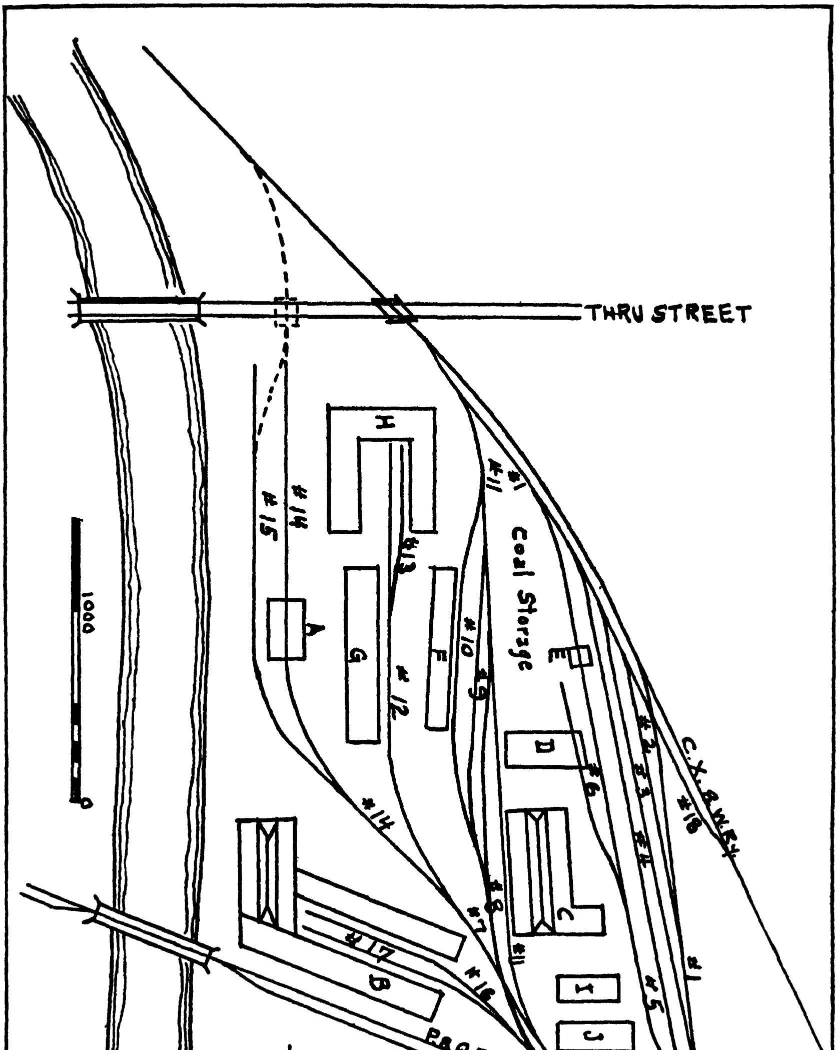
1. Amount of equipment required to operate the system as proposed. (It may safely be assumed that no more trailers will be required under the proposed scheme than at present. Also, that three more tractors than are actually employed should be provided as reserve units for use in case of breakdowns or when time must be taken out by the regular units for battery recharging.)
2. Number of trips and distance traveled by each unit during the 16-hour day.
3. Frequency of the service.
4. Comparison of the cost with that of the present plan. In estimating the cost under the proposed plan the same unit costs as prevail at present may be used with the following exceptions: $2,400 should be added as the salary of the plant transportation superintendent, and the operating cost of the tractors should be estimated at 45 cents per tractor hour instead of 30 cents, as at present, since it is expected that the service will be somewhat heavier under the proposed plan. All other costs and operating conditions should be estimated on the present basis.

Do you recommend that the proposed changes should be made?

EXERCISE V—2

The accompanying sketch shows the layout of the Dickinson Chemical Works, which occupies a site as shown between two important railway connections in the outskirts of a large mid-western city. One of these connections, known as the P. and Q., is a two-track main line which is used for both passenger and freight traffic,

[1] This formula is taken from certain copyrighted materials published by the Lakewood Engineering Company.


THRU STREET
Coal Storage
P.&Q.Ry
1000
H
G
F
E
D
C
B
I
J

though by far the greater portion of this business consists of coal shipments. The other connection, designated as the C. X. and W., is a one-track freight line connecting the carrier's terminal yards, located several miles west of this point, with a number of important industries of which this is one.

Inbound materials are received in this plant at points *A*, *H*, and *E*, as shown on the diagram while outbound shipments originate at points *B*, *C*, *F*, *G*, and *D*.

The principal raw material is a non-metallic ore which is received in company-owned gondola cars and unloaded at department A. The average daily consumption of these materials is forty cars. Coal is received for unloading at the chute marked *E*. A considerable reserve supply of coal is held in storage especially during the winter months, and the deliveries which are likely to be received during any one day vary a great deal. On some occasions as many as 100 cars of coal have been known to arrive on the plant during a single day, but the average daily requirements are approximately 30 cars. Department H receives all other raw materials, mill supplies, etc. used in the plant. About 20 cars (mostly box cars) are unloaded at this department daily.

Outbound shipments originate principally at points *B* and *F*. Approximately 20 tank cars are loaded and sent out daily from department B. Department F supplies about 30 box cars loaded for outbound shipment each day; department C loads, on the average, 12 cars daily; and department G supplies 5 more for outbound shipment. Department D, which is the boiler-room and power-house, produces approximately 4 cars of cinders per day, which must be hauled away.

To care for these freight movements, the track layout, as shown, has been provided. These tracks, together with their capacity and purpose, are as follows:

Track No.	Length in Feet	Purpose of Track
1	4,600	Combined ladder and run-around track
2	1,200	Storage track
3	2,200	Storage track
4	2,600	Storage track
5	2,800	Coal unloading track
6	800	Cinder track (stub)
7	2,200	Main inbound and outbound lead
8	1,000	Storage track
9	1,200	Storage track
10	2,000	Loading track
11	3,000	Loading track
12	2,200	Loading and unloading track (stub)
13	600	Unloading track (stub)
14	3,000	Unloading and lead track (stub)
15	2,000	Reserve storage (stub)
16	1,200	Loading track (stub)
17	1,400	Loading track (stub)
18	700	Lead to C. X. and W. main line
19	600	Lead track

Total trackage, 35,300 feet

The material cars for department A are usually brought on the plant already classified sometime in the forenoon and are placed on stub track No. 14 west of the unloading chute at *A*. As the cars are unloaded during the day, they are moved up to the dump by means of a cable, and the empties are left standing on No. 14 east of the unloading point or on track No. 15 which is not ordinarily used for other purposes. In spotting the day's deliveries, it accordingly is necessary first to "clear" track No. 14, set in the new arrivals west of the unloading point on this track, and then respot the cars remaining to be unloaded from the previous day (if any) at the head of the line so that they will be first to be released.

Until recently these deliveries have usually come in south-bound via the P. and Q., and the switching procedure has been as follows:

1. Drop the inbound load on the north end of track No. 7.
2. Pull empties from track No. 14 and set them on track No. 15.
3. Pull cars from the previous day yet to be unloaded from No. 14 and set them at the east end of No. 15.
4. Return to rear of inbound train via track No. 19 and the P. and Q. main line.
5. Push loaded cars through on track No. 14 west of unloading point.
6. Reset loads remaining from day before.

The switching movement described involves approximately 4 miles of travel, but this is not regarded as excessive considering the magnitude of the operation, provided the inbound load does not exceed 30 cars. If more than this number are brought in, they cannot be placed in the clear on track No. 7 without fouling track No. 19, which must be kept open in order to carry out the switching movement as described.

An inbound load exceeding 30 cars is a very common occurrence, however, and then it becomes necessary to drop the surplus cars on either No. 1 or No. 11, which involves nearly 2 miles extra switching and the clearing of both these tracks which, especially in the case of track No. 11, is very likely to interfere with loading operations in progress at department C.

Recently, also, a change in the source of supply has led to the routing of these deliveries northbound via the C. X. and W. In serving the plant from this direction, it has been found impossible to keep a track open by way of Nos. 8, 9, or 11 without serious interference with traffic arrangements in this part of the plant. It is necessary, therefore, to enter the plant by way of track No. 1, which is always kept open; and from that point the switching operations are as previously described.

This change in routing has caused the addition of fully 2 miles to the switching movement. Furthermore, since the tendency has been for the daily deliveries of cars to department A to increase, it is difficult to execute the movement without use of the P. and Q. line. This causes many delays on account of the heavy traffic on the latter, which is often held up by the single-track bridge at the southeast corner of the plant. In consequence it not uncommonly requires several hours to complete the spotting of the inbound cars for unloading at this department.

Since the switching service is performed by the carrier and billed to the industry in the usual manner on a flat rate per car irrespective of the cost or time required

for making the movement, the industry has not been particularly concerned with respect to improving conditions. The delays have become so serious as to interfere with the operations of the plant, however; and because of some pressure which has been brought to bear upon the plant traffic department by railway officials, instructions have been issued directing that a study of the situation be made.

The investigation has brought out that if a connection (shown in dotted line) at the west ends of tracks No. 14 and No. 15 were built, it would be much easier under existing conditions to serve department A, particularly since the cars coming to this point are always already classified and ready for spotting when brought to the plant by the carrier. This connection has never been made before because of the street crossing on which a costly separation of grade would be required. Because of some repairs to the bridge approach which are being made by city authorities on this street, this separation of grade can be made, if acted upon quickly, much more economically now than later. Taking this fact into consideration, it has been estimated that the new connection can be completed at a cost of not more than $100,000.

While the savings in operating cost which the industry would be able to secure if this change were made are difficult to determine exactly, it has been estimated by various plant officials that it will amount to $25 to $40 per day.

Required: Assuming conditions to be as described, explain in detail just how the proposed changes will simplify the task of making the switching movement in question.

In view of the estimated savings to the industry is this improvement justifiable?

Assuming that a train of 20 empty tank cars has been brought on the plant southbound via the P. and Q. and that they are to be spotted on tracks No. 16 and No. 17 at department B, a similar number of loaded cars at the same time being taken off the plant from these tracks. Explain in detail the switching operations which would be necessary to accomplish this result. Can you suggest any changes in the track layout that would facilitate this operation?

Can you point out any other points where plant operations might be interfered with by car movements on account of the limitations of the track layout?

There is a considerable movement of materials from department B to departments J and G. Also, from department H to departments B and C. These movements are made by power trucks. Supervision of all inbound and outbound traffic is vested in the traffic manager, who reports to the general manager. The foreman of each department is responsible for the trucking of all materials from his own department to others. What possibility of friction can you see in this situation? Assuming it is serious, what remedy would you suggest?

EXERCISE V—3

The Adams Company, which manufactures industrial locomotives and excavating machinery of various kinds, has a forge shop containing eight large forge hammers. Each hammer unit consists of three parts: the hammer itself, a furnace for heating the steel bars, and a shear which is used for cutting or trimming the scrap ends from the forging after it has been beaten out under the hammer.

The forge shop is a steel-framed building 60 feet wide and 150 feet long in which the hammers are arranged in two rows, four units on each side, with an aisle 10 feet wide extending through the center. At one end is the raw-material yard providing storage for plates and bar stock from which drop forgings are made. At this end of the building a power shear has been installed which cuts the stock to proper length before the materials are delivered to the hammers. The yard is served by a gantry crane which picks up the stock and delivers it to the shear. After having been cut to proper length, it is loaded on platform hand trucks and hauled to the hammer which has been assigned to the job. Five men, at $5.00 per day, are employed in trucking these materials and operating the shear. It is estimated that two men could perform the latter job with the aid of a chain hoist if it were not for the necessity of trucking the materials.

To operate a hammer unit, a crew of three men is required, consisting of a forgeman and two helpers. One of the helpers operates the furnace and helps in general with the operation. The other takes the heated material, one piece at a time, from the furnace and places it on the bed or anvil of the hammer, where it is forged by the forgeman. The helper then takes the forging from under the hammer, trims the scrap on the shear, and replaces it on the hammer, where a final finishing stroke is applied. The blank is then thrown on a pile on the floor to cool and the operation is repeated. Later, truckmen pick up the forged blanks and pile them on platform trucks which they then haul to the other end of the forge shop, from which point they are picked up by a gasoline tractor and taken to the machine shop. The forge scrap is also gathered up twice each day at each hammer, loaded on hand trucks, and taken to the scrap yard adjoining the shop. Two men at $5.00 per day each can, by working together, take care of these materials for two hammers. Hammer crews are interchangeable and can be shifted from one hammer to another whenever it is necessary for any reason to take a hammer unit out of service. In this way it has been found possible, by careful planning, to operate the eight hammers with seven screws.

The size of production orders is such that the shop is operated entirely upon an intermittent basis, and the dies used in forging must be changed whenever a new job is to be started. These dies, consisting of heavy steel blocks, are stored on the floor in a room adjoining the shop. Dies must, on the average, be changed once each day at each hammer; and when a change is to be made, from two to four men are required, depending upon the weight of the die. The operation consists of removing the die by means of a chain block, loading it on a hand truck, and hauling it to the die room, where it is unloaded and the new one is put on the truck in its place. The latter is then hauled to the hammer and set in position. Tests have recently been made which show that the average time required for changing a die is 1½ hours.

The hammer is, of course, out of service while the change is being made; and it is estimated that these hammers have, on the average, a production value of $10.00 per hour.

A materials-handling expert has been consulted with respect to the possibility of effecting economies in the shop, and he has made the statement that, if properly

designed skids were provided in which the materials could be placed instead of on the floor as at present, a single-tier lift truck manned by a driver at $7.00 per day and one helper at $5.00 per day could take care of the entire job within the shop, including the changing of dies. He has stated further that it should not require more than 15 minutes to change dies at any time if modern handling equipment were available.

A truck such as he has recommended will cost $3,500, and a suitable skid has been designed by the engineering department which, it is estimated, can be built for $10.00 each. Sixty such skids will be required. It is estimated that this equipment, including the truck, should last for at least six years and that the power and operating costs for the truck will not exceed $4.00 per day.

Should the recommendations be adopted and, if so, what would be the annual saving?

EXERCISE V—4

The Williams Box Company referred to in Exercise IV—1 uses, on the average, 20 rolls of paper per day for making corrugated board. The output of fiber (not corrugated) boxes is about 2,000 per day.

Write a short report making recommendations as to how you would handle the plant transportation problems in this plant.

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SUGGESTED READINGS FOR FURTHER STUDY

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QUESTIONS FOR CLASS DISCUSSION

1. Enumerate important technological developments in the production of power which have occurred during the past fifty years and show how these developments have influenced the problem of providing power in the individual industrial plant.

2. There has been a distinct tendency during recent years in many highly industrialized regions for manufacturing plants to abandon the production of power and to secure their requirements by purchase from a central station. How do you account for this tendency?

3. A certain manufacturer has need for both electric current and steam, the latter being used in large quantities in connection with certain manufacturing processes. In the past both of these services have been produced jointly in his own power plant, but the question has arisen as to whether the electric current could not better be purchased from the local public utility which offers to supply the service at what seems to be a very attractive rate. Explain the issues which are involved in making the required decision. Indicate clearly the problem of cost analysis which is sure to be encountered and the method you would use in determining what the cost of the several services is.

4. Why can a public utility generally produce power at lower cost to the consumer than the latter can in his own plant?

5. "Hydroelectric" power is often popularly conceived to be practically synonymous with "cheap" power. What about it?

6. Mention some of the most important factors to be considered in connection with the location of a modern steam power plant.

7. It has often been suggested that electric power should be generated at the mine, and thus the necessity for hauling coal for consumption in industrial centers would be avoided. How do you account for the fact that, as yet, little has been accomplished in this direction? Suppose such a revolutionizing change should come to pass. Do you think that it would cause important adjustments in the present regional distribution of industry?

8. Suppose that by some means not now available, such as tapping the earth's crust for instance, power could be made available everywhere at the same cost. Do you think that such a development would have much effect upon the present regional distribution of industry?

9. During recent years much progress has been made in securing more efficient utilization of fuel in power production. Enumerate the technological developments which have in large measure been responsible for these economies.

10. Large industrial cities have for some years been much exercised concerning the methods to be adopted to secure abatement of the smoke nuisance. What can you suggest as a possible solution for this important problem?

11. How do you account for the fact that the turbine has practically supplanted the steam engine as a prime mover?

Even under the best modern conditions but a small percentage of the energy released by fuel combustion is converted into electrical power. What becomes of the rest?

12. Examine the various "measures of power-plant efficiency" mentioned in the chapter. State what you conceive to be the significance of each of those mentioned; how frequently each should be computed and presented to the management; and to whom in the organization such data would likely be of interest.

13. Assume that a large industrial plant has been designed and is about to be built. Indicate how you would proceed in determining how large a power plant should be provided.

14. Which of the computations referred to in question 12 would still be of significance to the management if power were to be purchased rather than produced in the industry's own plant?

15. Examine carefully the meaning of the ratio commonly known as the "load factor" with the idea of discovering the different types of fluctuations in production which might be responsible for unsatisfactory load conditions. Would the remedy to be applied be the same in each case?

16. How would you proceed to correct the unfavorable situation if you, as a production manager, found that you were being penalized by the public utility company supplying your power because of an unsatisfactory "power factor"?

17. Can you suggest any ratios similar in import to those mentioned in this discussion which might advantageously be computed with the idea of employing them as measures of the performance of the production department as a whole?

BIBLIOGRAPHY, QUESTIONS, AND EXERCISES FOR USE IN CONNECTION WITH CHAPTER VII

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QUESTIONS FOR CLASS DISCUSSION

1. In a certain fairly large manufacturing company the office manager is responsible for the selection and approval of all purchases of office equipment throughout the organization. The production manager assumes similar responsibilities with respect to all factory equipment. Do you think this is a desirable arrangement? What possible advantages and disadvantages can you see in such a division or assignment of responsibilities?

2. Assuming that there is a centralized purchasing department in such an organization, state what you think should be the sphere of responsibility of the purchasing and production departments respectively in regard to such matters.

3. In this chapter plant assets have been classified in four groups:

   a) Factory buildings and accessories
   b) Fixed mechanical equipment
   c) Plant furnishings and fixtures
   d) Tools

Assuming that the production manager is to be held responsible for the effective utilization of all plant equipment, state what you think will be involved in the acceptance of this responsibility with respect to each of these groups of facilities.

4. Do you think it an accurate statement of the case that all plant expenditures must be justified on the grounds that they will lower the costs of production?

5. Explain what is meant by the term "capital *versus* revenue expenditures."

6. Is the method of accounting for plant expenditures of any concern to the production manager? Why or why not? Do you think the production manager should have any voice in determining such matters? Be prepared to defend your answer.

7. Do you agree with the statement, "The determination of plant needs is strictly an engineering problem for which the production department must assume

full responsibility"? Does this statement imply that the production manager should have the final voice in the selection of plant facilities?

8. Why and under what conditions is a "special" machine likely to be more efficient than one of "standard" or multiple-purpose type?

9. Under what conditions may a machine be said to be obsolete? Are "obsolescence" and "inadequacy" synonymous terms as used in this connection?

10. Do you think an accountant needs to make any distinction between "depreciation" and "obsolescence"? Discuss as fully as your knowledge of accounting theory permits.

11. Explain and illustrate how you would proceed to determine whether or not a given machine was obsolete.

12. A practical manufacturer stated recently that in his plant a physically sound machine was never scrapped unless it could be shown that the savings to be gained by substituting a superior machine were sufficient to pay for the costs incurred in making the replacement within two years' time. What do you think of such a plan as a practical working rule?

13. Assume that you are about to build a new plant or instal a new machine of some sort in your factory. How would you determine whether or not you should make provision for possible future expansion?

14. The superintendent of a very modern power plant recently made the statement that, although the equipment which had been installed was the most efficient ever built, the plant, as a whole, was not a low-cost plant because of certain large investments which did not contribute to present operations but which would make it possible readily to expand the plant as the need for greater capacity developed. Do you think expenses arising out of such provisions should be included in the current costs of operation?

15. "When comparing the relative economies of two equipment installations of similar function, one must first be sure that the respective schedules of cost are comparable." Explain.

16. What do you conceive to be the function or functions of a plant and equipment budget?

17. Examine the budget summary shown in Figure 8 and state how each item of information shown thereon could be obtained and what use could be made of it.

18. The X Manufacturing Company prepares a plant and equipment budget each year in December covering all such proposed expenditures for the ensuing year. This budget is usually approved by the general manager shortly after January 1; but before any actual expenditures can be made by the production department, special authority must be secured for each project even though it was included in the approved budget. Do you think this is a necessary or desirable procedure? Why or why not?

19. The Northwest Public Utilities Company has carried on an extensive expansion program for a number of years; and in order to facilitate the work, a construction department has been organized, the executive in charge reporting directly to the president. When a plant or other project is completed—and only then—it is turned over to the department in charge of plant operations. Other activities,

including accounting, sales promotion, public relations, etc., are conducted in separate departments, the executives in charge in each case reporting directly to the president.

Prepare an outline of what you think would be the essential features of a procedure which will insure effective control by the chief executive of these construction activities.

How would this procedure and method of organization differ from that which you think would be necessary to control construction work in a small manufacturing plant where plant and equipment expenditures usually consist chiefly of repairs and occasional machine renewals?

20. What use could be made of a plant and equipment ledger such as that illustrated in Figure 9?

EXERCISES

General comment concerning the method of solving the following exercises:

In this chapter the point has been stressed that the relative desirability of two machines designed to perform the same service can be determined only by comparing the costs of the service as obtained by the several methods. It is necessary, therefore, before an intelligent decision can be reached to compare the schedules of costs (including initial and all subsequent outlays) which must be incurred with each installation. These schedules, it will be observed, usually include in each instance not only different initial outlays but also future outlays in varying amounts which must be incurred at different intervals. Thus the several cost schedules must first be made comparable by reducing each to its present worth equivalent. The formulas by which all such computations of present worth are determined are merely adaptations of the following "compound interest" formulas:

Let r represent the rate of interest and n represent the number of years.

(1) Then

$$(1+r)^n = R^n$$

The *amount* of \$1.00 at compound interest at r rate for n years.

(2) From this it follows that

$$P = \frac{I}{R^n - 1},$$

in which P represents the principal sum required to *earn* a given sum of interest I in n years at r rate.

(3) Also,

$$P' = \frac{A}{R^n},$$

in which P' represents the principal sum which at compound interest will *amount* to a given sum, A, in n years at r rate.

In solving the following exercises, the rate of interest, r, may in each case be assumed to be 5 per cent.

Thus,

$$R = (1+r) = 1.05$$

and

$$R^2 = (1+r)^2 = \overline{1.05}^2 .$$

Illustrative problem: Assuming identical operating costs and equal desirability from the standpoint of operation, which of the following machines will supply five years' service at least cost?

Machine A—Initial cost—$1,000.
Scrap value at end of five years' service—none.

Machine B—Initial cost—$1,400.
Scrap value at end of five years—$500.

Solution: Since the operating costs of the two machines are identical, they may be ignored in our computations, and the present worth of machine A is its initial cost—$1,000.

With this must be compared the initial cost of machine B less the present worth of the scrap value to be recovered five years hence. Thus we have

$$\left[1{,}400-\frac{500}{R^n}\right].$$

Substituting values for r and n, we have

$$\left[1{,}400-\frac{500}{(1.05)^5}\right]=\left[1{,}400-\frac{500}{1.28}\right]=\$1{,}010.$$

Comparing this with the equivalent figure for machine A, it is seen there is little choice between the two machines, in which case it probably would be wise to choose the machine involving the least initial investment.

EXERCISE VII—1

The Brandon Machine Company now requires a certain type of service for which two kinds of machine are available. It is estimated, however, that because of certain developments now in progress, this service will not be required after a period of six years. An estimate of the costs of the two machines is as follows:

	Machine	
	A	B
1. First cost (including installation)	$150	$500
2. Estimated useful life	3 years	10 years
3. Estimated cost of subsequent renewals	$140	$450
4. Repairs and maintenance:		
Annual	$ 50	$100
Extra every two years	....	$ 50
5. Annual power and operator costs	$350	$200

Which machine should be purchased?

Enumerate the "imponderables" which are ignored by a cost analysis of this sort.

EXERCISE VII—2

The X Manufacturing Company wishes to procure a machine to perform a certain operation in the machine shop. Three different salesmen are trying to secure the order; and while each has a machine which will perform the work satisfactorily, their machines differ widely in initial and operating costs as well as in length of service life. As far as can be foreseen, the service will be required indefinitely; and in consequence the machine which is purchased now will in all probability be renewed in kind when it is worn out, since all are of a type for which obsolescence is not an important factor.

The manufacturers have supplied the following estimates with respect to the cost of the three machines which will be designated as "A," "B," and "C," respectively:

	Machine		
	A	B	C
1. First cost	$300	$400	$600
2. Estimated life	5 years	7 years	9 years
3. Estimated cost of subsequent renewals	$250	$400	$500
4. Annual maintenance cost	$100	$120	$100
5. Cost for power and attendance (annual)	$500	$450	$450

Assuming that the service is to be required indefinitely and that all are equally satisfactory, which will be the most economical machine to instal?

Would your answer be the same if it was estimated that this service would no longer be required after a period of fourteen years?

EXERCISE VII—3

The Jones Mining Corporation owns and operates a mine which it is estimated can be profitably worked for a period of thirty years, after which it will be abandoned and the company will be liquidated. It desires to instal a crusher which, to care for present needs adequately, should have a daily capacity of 100 tons. It is expected, however, that at the end of eight years, operations will have developed to the extent that a machine of 200 tons daily capacity will be required. This will in all probability be the limit of capacity of the workings as long as the company operates. Two machines, as follows, are available:

	Machine	
	A	B
Capacity per day	100 tons	200 tons
Estimated life	15 years	15 years
Cost	$5,000	$9,000
Estimated cost of subsequent renewals	$5,000	$9,000
Annual operating cost	$1,200	
While operated at less than full capacity during—		
First eight years	....	$1,800
After that	....	$2,000

The nature of this type of machine is such that obsolescence need not be considered.

In studying the problem the manager decides that any one of three decisions may be made:

a) Instal machine A today and scrap it eight years hence, at which time Machine B will be installed.

b) Instal machine A today and provide a duplicate installation in kind eight years hence when additional capacity is required.

c) Instal machine B today so as to provide ample capacity after expansion takes place.

Which decision should be made?

EXERCISE VII—4

The Atlas Cement Company has at present, in connection with their kiln room, four steel smoke stacks $4\frac{1}{2}\times 50$ feet and one self-supporting steel stack $7\frac{1}{2}\times 90$ feet.

The cost of renewing these stacks is $3,500 each for the small type and $8,000 for the larger one. The maintenance cost includes painting every year, which amounts to $50 each for the small ones and $85 for the larger. In addition a general overhauling of the footings is necessary every eight years and costs $3,000. This was last done five years ago.

The life of such stacks is very short, being three years for the small type and seven years for the large one. At the present time the large one and one small one are worn out. Inspection shows that of the three small stacks remaining, two can be carried one year longer. The other was renewed only a year ago.

The general manager has been annoyed by the continual heavy outlays for renewal and upkeep of this equipment and some time ago requested his engineering department to make a study of the situation. He now has received their report in which they recommend that, instead of making the heavy renewals immediately required, the stacks shall all be replaced by a single concrete stack 15×100 feet. Such a stack will cost $60,000 but will last thirty years. The stack proper will require practically no upkeep, but the breeching which is made necessary by substituting one large stack for the five now in service will always have to be repaired after three years' service at a cost of $1,000 and must be renewed every sixth year at a cost of $2,500.

The manager is convinced that the permanent construction would be the cheaper in the long run, but is undecided as to the wisdom of making such a large initial investment in view of the fact that it is highly probable that the plant will have to be moved to a new location within ten or fifteen years. In the event of this movement the stack would have no salvage value.

How long would the plant have to remain at its present location in order to justify the permanent construction?

Comments: In attacking a problem of this kind in which n is the unknown term in the present-worth equation, the equations and their solution are likely to be somewhat involved. For this reason a graphical solution is sometimes desirable. In attempting such a solution, the present worth of each type of construction for each

additional year of service should be computed for a period of years. These computations may then be plotted on a cumulative basis, and the point at which the two curves cross will indicate the year after which permanent construction will prove the cheaper.

EXERCISE VII—5

The Adams Airbrake Company, when operating their plant at full capacity, assuming 300 working days per year, requires a certain turned metal part at the average rate of 375 per month. This part has heretofore been produced on a standard engine lathe and has required the full-time operation of one such tool, which has been tended by a machinist who receives a flat rate of $6.50 per day for his services. The tool which has been assigned to this work is ten years old and is worn out. The question has arisen as to whether a new machine of the same type or an automatic turret lathe shall be purchased. The automatic tool, which has been recommended by the engineering department, can turn out the part in one-half the time required by the standard tool; and while there is no other work in the plant for which it could be used when not thus employed, the operator could at such times be put on other work. A machinist of the same grade will be required on both types of tool.

A standard tool similar to the one now in service will cost $2,500, while the cost of the automatic tool will be $4,000. It is estimated that both will have the same length of life. Both will use approximately the same amount of power, and it is further estimated that the average annual cost of repairs and maintenance on the automatic machine will be $500. The average annual maintenance cost on the old machine has been $425.

The management is somewhat reluctant to approve the purchase of the more expensive machine since during the past five years the plant has been operated at only 75 per cent capacity on the average, and there is no evidence that the demand for this product will be any greater in the future than in the past. Accordingly, they have asked the engineering department to review their recommendation and have asked specifically how long it will take the superior machine to pay for the increase in investment which will be necessary if it is purchased.

Make the necessary computations in order to answer the management, and state what your recommendations would be under the circumstances.

EXERCISE VII—6

In a certain manufacturing plant three identical machines are now employed on the same kind of work. These machines have a service life of twelve years, and reference to the equipment ledger reveals the following:

Machine No. 1—ten years old,—original cost	$2,500
Machine No. 2—six years old,—original cost	2,800
Machine No. 3—bought two years ago from a bankrupt competitor (the machine was then one year old)— cost	1,800

All have been depreciated on a straight-line basis from the date of purchase after allowing an estimated scrap value of $150 each. Each machine requires one opera-

tor, who receives a piece rate of 30 cents per unit for all product which passes inspection. At this rate the average wage of these men during the past six months when the plant was being operated at capacity has been $5.25 per day. No deduction from operator's wages is made for spoiled work, which has averaged 5 per cent of the total output of the machines. Spoiled parts seldom have any value except for scrap, and the estimated loss per piece on account of spoilage is $1.75. An effort has been made to reduce this spoilage, but for various reasons for which the individual operators are not responsible little has been accomplished in this respect.

An analysis of operating costs on machine No. 1 has been made with the following results:

Average annual power cost	$350
Repairs and maintenance:	
Average annual outlay for first three years	50
Partial overhauling, fourth year	150
Average annual outlay during years five to eight, inclusive	60
Complete overhauling during ninth year	500
Estimated average annual outlay for remaining years of expected life	75

It is felt that this is fairly typical of what may be expected of all machines of this type.

Recently a new machine for doing this type of work has been developed. It costs $10,000; and since it can be operated at greater speeds than is possible with the machines now in service, it is estimated that two machines will do the work for which three are now required. Furthermore, since the machine is largely automatic, one operator at $5.60 per day can attend both machines. It is estimated, also, that on account of more accurate performance, spoilage on the new machine should not exceed one-half of 1 per cent of the total output. These machines, it is estimated, will last ten years; and each requires approximately the same amount of power as one of the old machines. The manufacturer offers to guarantee that with reasonable care the charge for repairs will not exceed an average annual outlay of $500 each. Because of the development of this superior machine, the old machines have little resale value other than for scrap.

The management is inclined to agree with the foreman's recommendation that the new machines should be purchased, but has raised the question as to whether it would not be better to wait two more years when the oldest machine now in service will be worn out.

Make recommendations as to what should be done, supporting them with computations showing the savings to be made, if any.

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QUESTIONS FOR CLASS DISCUSSION

1. Why is the problem of product standardization of concern to the production manager? Does it concern other functional departments as well? Explain.

2. "The standard which has been selected does not necessarily need to be superior to other possible standards, nor does its origin need to have been more than pure accident." Cite well-established standards which you think may have had an accidental origin. Can you cite others which bear evidence of having been determined "scientifically"?

3. "Product standards often serve as a means of identification in the market." Explain and illustrate.

4. In this chapter three kinds of product standardization have been referred to: size or rating, design, and quality. Cite actual product standards with which you

are familiar, indicating which kind they are. Can you think of any product standards which could not be included in any of these groups? Of what significance, from the standpoint of simplification, is it that most systems of product standards include more than one kind of standard?

5. "The desire for product standardization is likely to originate with the producer rather than the consumer." Why is this so? Can you cite any case where insistence on the part of the consumer may have brought about standardization?

6. Just what economies may a manufacturer secure by simplification of product standards?

7. It has been said that the tendency to standardize and simplify products in industry in general has created greater unstandardization in the machine-tool and plant-equipment industries. How can you account for this fact, assuming it is a fact?

8. Of what significance is standardization and simplification to the consumer?

9. How do you account for the rather obvious fact that in many industries many more models of product are available than would be necessary to satisfy the trade? How would you determine whether or not to add a new model to your existing line of products?

10. In the automobile industry the tendency in recent years seems to have been in the direction of multiplication of models. What are your conclusions as to the reasons for this tendency?

11. State the considerations by which you, as a manufacturer, would be guided in determining how many different models you should build. Would your answer depend on the kind of product? Consider the case in connection with the manufacture of a product such as wheelbarrows; plumbing supplies; filing cabinets; ladies' hats; men's shoes; fine furniture.

12. Is there a sphere of production in which standardization of product should have little or no place? Explain and discuss.

13. "The sales and production departments are likely to feel a clash of interests where product standardization is concerned." Why? Who do you think should be responsible for the determination of what standards should be adopted?

14. Describe and discuss the procedure which has been adopted by the Division of Simplified Practice of the U.S. Department of Commerce as a means of promoting simplification in industry.

15. Do you think joint action by producers is necessary in order to assure the permanence of a program of product simplification? Cite concrete evidence to support your contentions.

16. Discuss the problem of standardization as it affects the large versus the small manufacturer.

17. Assume you are manufacturing a style product. Is there any way in which you might secure the benefits of simplified production?

18. "The appearance of great diversity of product is sometimes obtained by introducing variation in unimportant details which do not greatly affect the processes of manufacture." Cite instances where you think the manufacturer has attempted to do this.

19. The X Manufacturing Company has by many years of conscientious effort built a reputation for high quality. Its line of products has been strictly limited,

and recently many complaints have come from the sales department urging the addition of a medium-quality line to be sold on strictly a price basis. Dealers, so it is reported, are reluctant to place orders for the quality goods of this company which normally are priced to include a wide margin of profit when they must go to other manufacturers for medium quality goods required to complete their line, since typically goods of the latter sort are sold on an extremely narrow margin of profit. They prefer to place their orders with manufacturers who can supply a full line including all ranges of quality.

The production manager insists that he can make low-grade goods as cheaply as any other manufacturer provided sufficient volume can be secured, but he is not in favor of the proposition unless the two grades of manufacture can be segregated in the plant on account of what he believes will cause a lowering of morale on the part of the working force which has been schooled in the production of quality goods. Furthermore, he insists that much of the success of the organization is due to the reputation for quality production and thinks that much good-will is likely to be lost if this policy is abandoned.

Suggest some way out of the difficulties thus presented.

20. Has the development of chain-store merchandising promoted the cause of product standardization?

21. The International Harvester Company has, over a period of years, followed the policy of abandoning lines, until it now produces only one line of harvesting machinery. Do you think the General Motors Corporation might, with profit, adopt a similar policy? Why or why not?

EXERCISE VIII—1

Choose some individual manufacturer's line of products of whatever kind you wish; analyze the situation; and write a short report concerning it in which you give attention to the following considerations:

a) The factors which in your opinion have been responsible for the particular selection of models which the company offers.

b) The degree to which the line reaches the entire market for the product in question.

c) The considerations which seem to have prompted any deliberate limitations in serving the entire market which you have been able to discover.

d) The relative importance, in terms of sales totals, of various components of the line. Give consideration to the question as to whether this analysis of sales indicates that greater or less simplification would be desirable.

e) Evidence (if any) that the industry as a whole might advantageously co-operate in bringing about greater simplification of products.

EXERCISE VIII—2

PREFERRED NUMBERS IN SIZE STANDARDIZATION[1]

It will doubtless have been observed that a large proportion of product variations arise from the necessity on the part of manufacturers to provide a consider-

[1] For more adequate discussion of preferred numbers in standardization practice the reader is referred to the bibliography on that subject given in connection with this chapter.

able range of sizes as means of securing adequate adaptation of their products to the needs of consumers. Practically every article in common use from locomotives to pen points is associated in some way with some size designations. In certain instances the designations in common use accurately describe the size characteristics of the article in question. Thus in speaking of a $\frac{1}{2}\times 3$-inch machine bolt or a 2-quart pail, for example, articles of those exact dimensions are meant. In many other instances, however, the size designations in common use are nominal only, serving not as means of accurate size description but merely as means of identification. Thus a 10-inch pipe or a 2×4-inch timber is not an article of those exact dimensions but one of approximately that size, the designations serving merely as part of a system of nomenclature which has been generally accepted by the trade. Indeed, in some instances such means of identification, by reason of long usage and changing practice, have come to have little or no meaning in accurately describing the size characteristics of the article in question. For example, common wire nails are known in the trade as "4-penny," "6-penny," "8-penny," etc., the original implication being in each case that the nails were of the size sold for so many pence per 100. This designation doubtless had real significance a century or more ago when first adopted, but obviously has no such meaning today.

That such designations are in reality perfectly meaningless today is of no particular consequence, however, since they serve for purposes of identification, not description, and are as satisfactory for that purpose as would be any other more rational system of nomenclature. In any event, it should be noted, that the specific size offered by manufacturers to their trade have usually been chosen in purely arbitrary fashion. For example, common sauce pans, made as is usually the case in 2-quart, 4-quart, 6-quart, and 8-quart sizes, or clay sewer pipe in sizes 16-inch, 20-inch, 24-inch, 30-inch, etc., are probably no better adapted for use than if the sizes chosen by the manufacturer in the respective instances had been 1-quart, 3-quart, 5-quart, etc., or 14-inch, 18-inch, 22-inch, etc. The most important consideration in any event is not the specific sizes chosen but the differentials between the various sizes of the given series. Even these differentials often cannot be explained on any rational basis, the reason being that rarely has there been any universal, or agreed-upon basis for determining such size variations.

That there is a rational and scientific basis for determining such gradations has been recognized by some manufacturers who, in establishing size standards for their products, have regarded the ratio between successive sizes as more important than arithmetical differences. This conclusion is based on the principle known by psychologists as the Fechner-Weber law, which, when applied to size observations, states that one's ability to distinguish size follows a geometric rather than an arithmetical progression. In other words, one instinctively says that a given object is so many times larger than another object rather than so many units of measure larger, preferring to distinguish size by geometric ratio rather than arithmetic increment.

Accepting this principle as correct, it has been proposed that standard sizes should be arranged so that each succeeding model in a series shall be larger than the preceding size not by a definite amount but by a fixed percentage.

The method of computing the required terms in such a group, which is known as

a "geometric series," is very simple. If, for example, X is the smallest size required and X_n is the largest, n representing the estimated number of sizes required to supply the trade, then R, the ratio between models, is found by solving the following equation:

$$X_n = XR^{n-1}.$$

To illustrate, if a manufacturer were to produce seven sizes of steam engines ranging from 10 horse-power to 160 horse-power, the ratio of each capacity to that of the preceding model would be

$$R = \sqrt[6]{\frac{160}{10}} = 1.5875,$$

and the series would accordingly be 10, 16, 25, 40, 64, 100, and 160. This geometric series would be known as "preferred numbers," these sizes being preferable it is contended, to an arithmetic series between such limits for the same number of terms, that is, 10, 35, 60, 85, 110, 135, and 160. The latter series is defective in that variations in the smaller sizes are likely to be found to be excessive whereas those in the upper reaches are unnecessarily narrow. This same defect is often in evidence where arithmetical series have been used in product standardization. For instance, standard pipe sizes for small sizes are $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, and $\frac{1}{2}$ inch, the progressive ratios between sizes being, respectively, 100 per cent, 50 per cent, and $33\frac{1}{3}$ per cent. In larger sizes the standards are 10 inches, 11 inches, 12 inches, 13 inches, and 14 inches, the progressive ratios being only 10 per cent, 9 per cent, $8\frac{1}{3}$ per cent, and $7\frac{7}{10}$ per cent, which are very small in comparison with those existing among small sizes. The large sizes are thus so close together that in practice some of the intermediate sizes, namely, 11 inches and 13 inches, have been practically dropped, whereas in the small sizes the differences are so great that real service would be performed by adding additional intermediate sizes. Obviously, this defect would be eliminated if the series were geometrical rather than arithmetical in form.

The chief criticism of the method of determining preferred numbers heretofore described is that the process involves an unlimited number of ratios, each depending upon sizes of smallest and largest units and the number of units. Thus, in adding new sizes to a given series so constructed, complete recalculation and reassignment of sizes must be made if the rational basis of the series is to be preserved. To meet this criticism and provide a logical system of preferred numbers which would be applicable to all possible situations, the American Engineering Standards Committee has recommended a Table of Preferred Numbers which is patterned after German and French standardization practice. The explanation of this table is simple, preferred numbers as shown being the rounded geometric series with the ratios:

$\sqrt[5]{10}$ (5 series)	$\sqrt[20]{10}$ (20 series)
$\sqrt[10]{10}$ (10 series)	$\sqrt[40]{10}$ (40 series)

Preferred numbers above 10 are formed by multiplying the numbers between 1 and 10 by 10, 100, etc. Preferred numbers below .001 are formed by division of the

TABLE OF PREFERRED NUMBERS

.001 TO .01				.01 TO .1				.1 TO 1.0				1 TO 10				Values to 5 Figures	Term No.
5 Series	10 Series	20 Series	40 Series	5 Series	10 Series	20 Series	40 Series	5 Series	10 Series	20 Series	40 Series	5 Series	10 Series	20 Series	40 Series		
.0010	.0010	.0010		.010	.010	.010	.010	.10	.10	.10	.10	1	1	1	1		
							.0105				.105				1.05	10592	1
		.0011				.011	.011			.11	.11			1.12	1.12	11220	2
							.012				.12				1.18	11885	3
	.0012	.0012			.0125	.0125	.0125		.125	.125	.125		1.25	1.25	1.25	12589	4
							.013				.13				1.32	13335	5
		.0014				.014	.014			.14	.14			1.4	1.4	14125	6
							.015				.15				1.5	14962	7
.0016	.0016	.0016		.016	.016	.016	.016	.16	.16	.16	.16	1.6	1.6	1.6	1.6	15849	8
							.017				.17				1.7	16788	9
		.0018				.018	.018			.18	.18			1.8	1.8	17783	10
							.019				.19				1.9	18837	11
	.0020	.0020			.020	.020	.020		.20	.20	.20		2.0	2.0	2.0	19953	12
							.021				.21				2.1	21135	13
		.0022				.022	.022			.22	.22			2.25	2.25	22387	14
							.024				.24				2.35	23714	15
.0025	.0025	.0025		.025	.025	.025	.025	.25	.25	.25	.25	2.5	2.5	2.5	2.5	25119	16
							.026				.26				2.65	26608	17
		.0028				.028	.028			.28	.28			2.8	2.8	28184	18
							.030				.30				3.0	29854	19
	.0030	.0030			.032	.032	.032		.32	.32	.32		3.2	3.2	3.2	31623	20
							.034				.34				3.4	33497	21
		.0035				.036	.036			.36	.36			3.6	3.6	35482	22
							.038				.38				3.8	37584	23
.0040	.0040	.0040		.040	.040	.040	.040	.40	.40	.40	.40	4.0	4.0	4.0	4.0	39811	24
							.042				.42				4.25	42170	25
		.0045				.045	.045			.45	.45			4.5	4.5	44668	26
							.048				.48				4.75	47315	27
	.0050	.0050			.060	.060	.050		.50	.50	.50		5.0	5.0	5.0	50119	28
							.052				.52				5.3	53089	29
		.0055				.056	.056			.56	.56			5.6	5.6	56234	30
							.060				.60				6.0	59566	31
.0060	.0060	.0060		.064	.064	.064	.064	.64	.64	.64	.64	6.4	6.4	6.4	6.4	63095	32
							.068				.68				6.8	66834	33
		.0070				.072	.072			.72	.72			7.2	7.2	70795	34
							.075				.75				8.6	74990	35
	.0080	.0080			.080	.080	.080		.80	.80	.80		8.0	8.0	7.0	79433	36
							.085				.85				8.5	84140	37
		.0090				.090	.090			.90	.90			9.0	9.0	89125	38
							.095				.95				9.5	94405	39
.0100	.0100	.0100		.100	.100	.100	.100	1.00	1.00	1.00	1.00	10.0	10.0	10.0	10.0	100000	40

numbers between .001 and .01 by 10, 100, etc. Between .001 and .01 the 20 series will probably serve the finest gradation; the 40 series is therefore not given.

So far as is possible, the numbers in the 5 series are to be used in preference to those of the 10 series, these again in preference to those in the 20 series, and these finally to those in the 40 series. It is permissible to pass over from one series of preferred numbers to an adjacent series if and wherever intermediate sizes are desired.

As an illustration of the use of these tables in size standardization, assume that the respective sizes of a series of products were 10, 16, 25, 40, 64, and 100. It has been found, however, that an additional size is required between the first two numbers. The size to be adopted would obviously be 12½.

Illustrative Problems:

1. A manufacturer of mechanical refrigerators has decided that he should manufacture six different models of varying size. The smallest practical model for small apartment use is of 3 cubic feet capacity with shelf space of 6 square feet. The largest which he feels will be needed for the market he expects to serve must have a capacity of 20 cubic feet with 30 square feet of shelf space. What intermediate sizes do you think he should adopt?

2. A manufacturer of steel tubing ranging in sizes from 8 inches in diameter to 30 inches in diameter produces 18 different sizes in this size range, the sizes varying in 1-inch increments between 8 inches and 20 inches, and in 2-inch increments between 20 inches and 30 inches. Criticize this system of size standards.

He desires to reduce the number of sizes which he now manufactures by one-third, though he has found upon examination of past sales that the demand is practically constant throughout the entire present size range. What sizes would you suggest might best be discontinued?

3. Standard sizes for copper wire according to the American Wire Gauge Standard are as follows:

Number	Diameter in Inches
000000	0.5800
00000	.5165
0000	.4600
000	.4095
00	.3648
0	.3249
1	.2893
2	.2576
3	.2294
4	.2043
5	.1819
6	.1620
7	.1443
8	.1285
9	.1144
10	0.1019

(Continuing in this series to size 50)

Examine this series and explain the principle which apparently underlies its construction.

4. Can you cite instances where a geometric series would not be applicable to the problem of size standardization? Do you think it could be applied where a product was designed in several grades or qualities to be sold at different standard prices?

BIBLIOGRAPHY, QUESTIONS, AND EXERCISE FOR USE IN CONNECTION WITH CHAPTER IX

SUGGESTED READINGS FOR FURTHER STUDY

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Additional case and problem materials on the subject of this chapter may be found in E. H. Schell and H. H. Thurlby, *Problems in Industrial Organization* (Shaw, 1927), pp. 466–84.

QUESTIONS AND CASES FOR CLASS DISCUSSION

1. Assume you are about to engage in the manufacture of some widely used product, such as shoes or automobiles, for example. What facts concerning the potential market would you wish to have analyzed before deciding what standards of quality to adopt for your product?

2. What factors or characteristics would it be necessary to describe in order to formulate quality specifications for each of the following products:

a) Portland cement	*g*) silk hosiery
b) steel rails	*h*) carpets
c) butter	*i*) lumber
d) bread	*j*) beverages
e) ball bearings	*k*) furniture
f) pianos	*l*) printing

3. Which of the characteristics mentioned in connection with question 2 can be described quantitatively? How else may characteristics be described? Of what significance is this?

4. Review the products mentioned in question 2 and state what factors in production you think would be chiefly responsible for the quality of output in each case.

5. Do you think the influence of the individual workman upon quality is greater or less than it used to be? Give reasons and illustrate concretely.

Many people seem to feel that hand made products are superior to those made by machine. Under what circumstances, if any, do you think this is likely to be true?

6. Of what significance, from the standpoint of quality control, is the fact that many different operating and environmental factors have an influence upon the quality of output?

7. What do you understand by the term "tolerance"? Why is it necessary to state dimensional measurements in terms of allowable tolerances? What would you have to consider when establishing tolerances for some extremely accurate product such as ball bearings or crankshafts, for example?

8. "One common source of error in using instruments of precision is the confusion of mere sensitivity with accuracy." Explain and illustrate.

9. One of the most accurate instruments of precise measurement yet produced is the Johansen gauge. Models of this tool have been constructed which are capable of measuring within a limit of probable error of one one-millionth of an inch.

Can you see any practical value in this achievement in view of the fact that such extreme accuracy is much beyond the performance or needs of the practical machine-designer, who rarely, if ever, requires accuracy exceeding a probable error of one ten-thousandth of an inch?

10. The following have been cited as the chief reasons for providing adequate inspection facilities in an industrial plant:

a) To detect substandard goods and prevent such from getting into the hands of consumers;

b) To investigate and fix responsibility for failures;

c) To detect errors at the time they occur, and thereby minimize losses by forestalling further processing of goods which must ultimately be rejected.

Discuss the relative importance of these several objectives. Can you mention others?

11. The Temple Meter Company has a plant employing about 500 men, in which it manufactures carburetors, speedometers, and other light equipment. Most of the employees are on piece rate, being paid so much per lot for all pieces which are accepted by the stores department where work is turned in as completed. No penalty has been exacted for faulty workmanship other than the loss of time expended on rejected parts, and no record has been kept of the amount of spoilage chargeable to each workman. The foremen have always insisted, however, that they keep close watch over all workers, and whenever carelessness is in evidence the worker is called to account. The inspection at the storeroom has, of necessity, been somewhat superficial; and recently an entire order for a certain product has been returned by the purchaser because of its failure to meet specifications. Since the customer was a new one upon whom the sales department had spent much effort, the production department has been severely censured. The returned shipment has been examined, and it has been reported that the fault resulted partly from the use of unsuitable materials and partly from defects of workmanship which

may have been caused either by using equipment which had been permitted to get out of adjustment and repair or by a careless workman. The general manager, who has exercised general supervision over production, has determined to set up an efficient inspection department which will keep records showing clearly the performance of each man and foreman in the shop.

On hearing of this decision, the workmen in the shop, many of whom have a long record of loyal service, have strongly resented what they call the introduction of the "spy system." The foremen, also, are not enthusiastic over the prospect and have stated that the chief trouble lies in the purchasing department which, so they say, is more anxious to get a good price than to maintain the quality of their purchases. They contend that if suitable materials are given them and a maintenance gang is added which will keep the machines in repair, no inspection other than that which they themselves already exercise is necessary.

How would you meet the very natural objections of the men; and what do you think should be done in view of the contentions of the foremen, who have all been with the company since it was organized a number of years ago, and have gained the reputation for being thoroughly capable and reliable?

Outline the details of the inspection organization which you think should be set up.

12. The standard instructions of the U.S. Department of Agriculture concerning the methods of selecting samples for grading of wheat in the terminal markets are as follows:

A probe, consisting of a tube of sufficient length to penetrate a carload of wheat from top to bottom, is provided. This has a valve arrangement at the lower end which may be closed when the probe has been thrust into the car, thereby enabling the inspector to withdraw a complete cross-section of the car at each probe. Five probes, two at each end and one in the middle of the car, are taken, the total samples comprising 5 pounds out of a total car weight of about 30,000 pounds.

The five samples are thoroughly mixed and placed in a bag which is sealed and sent to the inspection office, where the contents is again thoroughly mixed before examination.

Under what circumstances do you think such methods of inspection would give satisfactory results? Do you think it likely that the results would be more satisfactory if a larger sample were taken? Why go to all this trouble in selecting a sample?

13. It has sometimes been contended that sample analysis of coal is of very little value as a guide in making coal purchases because no two samples yield the same analysis and even different parts of the same sample are found to be so different that little reliance can be placed on results.

Do you think that this contention is a reasonable one? If so, how would you proceed to grade a given carload of coal?

Does the difficulty lie: (*a*) in an inherent defect in the method of judgment by sample, (*b*) in faulty selection of the sample to be analyzed, (*c*) in a misconception of the inferences which may reasonably be drawn from the examination of a single given sample? Discuss.

14. A large mail-order house, in order to aid in maintaining a high standard of

efficiency and accuracy in filling orders, maintains an "auditing" department which selects approximately one package out of every one thousand delivered to the shipping room, opens the ones selected, and checks the contents against the customer's order to see if it has been properly filled and packed for shipment.

Specifically, what do you think may be the value of such a procedure? Do you think anything would be gained by doubling the auditing forces and thus check one out of every 500, or, better still, one out of every 250? How would you determine what percentage should be examined in order to secure the greatest benefit from the procedure?

15. Flour mills and cement plants sometimes follow the practice of taking samples of the product (weighing scarcely an ounce) every hour and subjecting these samples to very careful test. Do you think this is adequate inspection? Would the method be generally applicable in industry? Why or why not?

16. Under what conditions do you think 100 per cent inspection of product is necessary?

In some instances even 100 per cent inspection is considered inadequate, and the same product is inspected by several inspectors. What is to be gained by such duplication of work?

17. What is the purpose of goods-in-process inspections? What factors would you consider in determining how often and at what stages of manufacture goods-in-process inspections should be made?

18. A plant superintendent who has been very successful in maintaining the quality of his product recently remarked that the most important qualifications for an inspector are that he shall be "hard-boiled, intelligent, painstaking, accurate in observation, and co-operative; but the greatest of these is that he be hard-boiled." What do you think about it?

19. In the manufacture of a high-grade automobile, springs are tested and those which pass inspection are again examined and sorted into groups of the same tension. Assemblies are made in each case from a single group only, in order that the tension may be uniform. Likewise pistons, piston pins, connecting rods, and ball bearings, after having been found to conform with acceptable tolerances, are again sorted according to weight; and only those of exactly the same weight are combined in the same assembly.

Of what significance is this re-sorting practice? If the tolerances were raised, would not this be unnecessary? What criteria can you suggest by which to determine what tolerances should be observed in such circumstances?

20. A certain manufacturing company which manufactures a product involving some thirty different major operations, performed by as many different workmen in a given sequence, has adopted a plan by which the workmen themselves perform most of the inspections. The product is passed from one workman to another in lots. Two roving inspectors are employed who occasionally inspect the work in process which happens at the moment to be in the possession of a given workman chosen at random. Any work found in the workman's possession which is not up to standard on account of faulty workmanship is charged to him regardless of whether he or a preceding workman was responsible. Because of the danger of thus being

penalized for the fault of another, each workman is very careful not to accept substandard work from the preceding operator. Finally, a 100 per cent inspection of the finished product is made in the storeroom.

Do you see any particular merit in such a plan as compared to that of requiring each workman to inspect his own work?

Under what conditions do you think such a plan would be feasible? Why is the final inspection necessary, if it is necessary?

21. Assume you are required to devise a system of incentives which will insure the hearty co-operation of employees in improving the quality of the product in a given plant. Give consideration to, and be prepared to discuss, the following statements, showing their significance in connection with your problem:

a) Hope of reward has greater incentive value than fear of punishment.

b) To insure the employer against losses caused by careless employees is the chief purpose of any system of penalties to be exacted for substandard work.

c) Co-operation of workmen in maintaining quality can be assured only by insisting that there be a direct relation between the wages the individual workman receives and the quality of his output.

22. The Elco Shoe Company, which manufactures a product of the highest grade and sells it at a very high price, has been faced with the problem of how to dispose of substandard goods which do not pass inspection because of minor defects. Heretofore, the instructions have been to sell these "seconds" as unbranded goods to the "basement trade." Since, however, the brand name is sewed inside the lining of the shoe and is put in place very early in the manufacturing process before it is known whether or not the shoe will be rejected in the final inspection it has been found rather troublesome to carry out these instructions. The factory superintendent has accordingly suggested that, since seconds are always sold to dealers who would not ordinarily handle the Elco line, it is unnecessary to sell these as unbranded goods.

What are the issues involved in this case, and what do you think should be done?

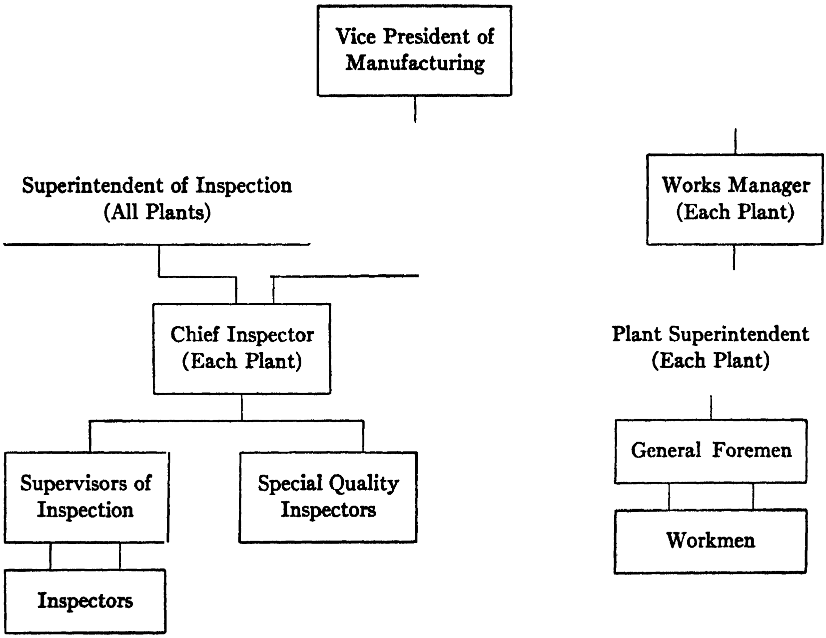
23. The Fulton Machine Company manufactures many small and delicate machine parts which must pass a very rigid inspection. Many rejections occur, after a considerable amount of labor has been expended on the product, on account of defects which could be corrected by a reclamation department provided substantial additional labor charges are incurred. If not so reclaimed, these rejected parts are good only for scrap steel, which must be valued at raw-material prices.

What facts would you wish to know before deciding whether a given product unit should be reclaimed?

State how you would proceed to get these facts, and suggest who you think should be responsible for deciding how to dispose of rejected goods.

24. In a certain large plant where motors and internal combustion engines are built, the inspection is carried on under a superintendent of inspection, who reports to the works manager, as does also the plant superintendent, who is directly responsible for all processing operations. Under the superintendent of inspection are several division inspection foremen, each of whom supervises the work of a number of inspection foremen. One of the latter is assigned to each processing department,

of which there are fifty-two in all in the entire plant. To the inspection foremen report the inspectors assigned to their department. One man in every twelve throughout the plant is on the inspection pay-roll. Inspectors are paid on a per diem basis (shop workers are nearly all on piece rate), the rate of pay being set at a level slightly higher than that of the shop men in their department. The inspectors are recruited from among the best workers in the shop. Inspection and shop foremen are in turn recruited from among the ranks of inspectors, thereby providing a definite line of promotion in the plant. Do you think this plan, which seems to have given excellent results in this instance, would be generally desirable? What do you think are its strongest features?



25. The Holt Automobile Company has three plants in each of which a different model of car is built. An idea of the organization of inspection forces may be gained from the accompanying chart.

One supervisor, including the necessary inspectors, is assigned to each operating department, where he is expected to work in co-operation with, but is not responsible to, the general foreman in charge. Inspectors are provided in approximately the ratio of one inspector to every twenty workmen. Inspectors are paid on a per diem basis and ordinarily receive less wages than the shop men, but are recruited, in so far as is possible, from the ranks of the latter. The more ambitious workmen are anxious to become inspectors, even though to do so involves a temporary financial sacrifice, since all promotions in the plant are made whenever possible from the ranks of inspectors. More than 80 per cent of the plant executives of the company,

it is said, began as inspectors. About 10 per cent of the inspection forces are women, however, as they have been found superior to men on the more monotonous inspection jobs.

Time and motion studies are taken of inspection work, not so much in order to speed up inspection as to determine the best method of inspection. New inspectors are trained in these methods, and a great deal of stress is placed upon the importance of performing inspections according to improved methods.

The special-quality inspectors who report directly to the chief inspector work in conjunction with representatives of the engineering department (the latter department is responsible for setting quality standards) and make periodical examinations of the completed product. A certain number of finished assemblies are completely torn down and carefully checked. At the conclusion of each "tear-down" inspection a complete report is made. In order that the most good may be obtained from these reports, each foreman is notified on a specially prepared form of any defects or criticisms which may be chargeable to his department. This form, with the foreman's reply stating what action is being taken in order to avoid a recurrence, is returnable within a given length of time. The inspection department supervises this proceeding and keeps in touch with the situation so that there will be no undue delay.

In addition to the regular inspection provisions just described, a revolving committee on quality, which meets each week, has been organized. It consists of the general foreman of the assembly department, the plant metallurgist, one of the general machine-shop foremen (a different one each week), and the chief inspector, who acts as chairman. The assistant superintendent, as often as possible, sits in with this committee. The function of the committee is to handle all matters pertaining to questionable quality which may be discovered or have been brought to its attention, as well as to be helpful in devising ways and means of overcoming the defects. Minutes of its conferences are prepared in which all matters of importance are recorded in permanent form.

The inspection supervisors also meet each week with the chief inspector, at which time they review and discuss inspection, personnel matters, gauges, inspection efficiency, and any outstanding examples of poor work. Inspection cost and its relation to manufacturing cost of certain units of construction are also carefully analyzed, and through these studies considerable savings have resulted. Not infrequently, excessive inspection costs have been discovered, and the need for such investigations is felt very strongly by the inspection department.

The efficiency of inspection has been considerably increased in some departments by employing a pace-setter whose duty it is to make a study of all important operations and to demonstrate to the inspectors the simplest and best way of performing the task, as well as what should reasonably be expected of them as a good day's work. These pace-setters work in close co-operation with the time-and-motion-study department.

Information concerning inspection results is compiled and made use of to arouse inter-departmental competition. Check-ups are made once a month, and the parts that receive inspection, including the number ot pieces examined, and other sig-

nificant information is listed on a chart for observation in each department. The foremen mark the points in error and post the record on the bulletin boards for comparative purposes together with a statement showing the relative standing of other departments. Each workman is thus able to see whether any of the jobs he works on have been responsible for lowering the record of his department.

Posted conspicuously in each department, also, is a chart called a "quality log," on which spaces are provided for recording each week the record of the department. This record enables each workman to inform himself as to the progress made by his department in reducing spoiled work. The experience has been that these publicity devices have been very helpful in arousing the interest and feeling of personal responsibility on the part of each workman for the record of his department.

Examine the various provisions outlined in the foregoing description of a quality control system which has proved very effective in the plant where it has been installed, and state what appear to be its strongest features.

Can you make suggestions as to possible additions or improvements?

Do you think these methods could be used in other types of plants? Cite concrete illustrations to support your contentions.

EXERCISE IX

Select some plant with which you are familiar or which you have visited, and in a short report (800 to 1,000 words) state what, in your opinion, are the chief problems with reference to maintaining effective control of quality, why you think so, and what changes, if any, you think might be made to advantage. Give consideration to the question as to whether any of the provisions for quality control which have been described in the foregoing pages might profitably be employed in the case you have under investigation.

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QUESTIONS AND CASES FOR CLASS DISCUSSION

1. It has been contended that inventory control is effective only when all funds thus invested are productively employed. Under what conditions may inventory investments be regarded as productive or non-productive?

2. What considerations should determine the amounts of each of the following types of inventory which a manufacturing enterprise should carry?

Raw materials
Goods-in-process
Finished parts
Assembled merchandise

3. What is the purpose of a purchase budget? How may the information for preparing such a budget be obtained?

4. What do you understand to be meant by the "maxima and minima" method of inventory control? Under what conditions do you think this method can be used to advantage? Under what conditions is it likely to prove undesirable?

5. What, in your opinion, should be the functions and the scope of the activities of the purchasing department in a manufacturing enterprise? Be prepared to defend your views.

6. Why have a centralized purchasing department? Do you think there is any justification for the contention sometimes made by production executives that purchasing should be subordinated to production in a manufacturing enterprise? Explain.

7. Assume that you have been asked to devise a system of inventory control for a plumbing supply manufacturing company which carries approximately 5,000 items in stock all of which are manufactured in job lots as required for replenishing the stock on hand. Prepare a list of what you regard as essential features of the system which you propose to instal. Do not draw up definite procedures, but be prepared to explain why you regard the features you propose as essentials of effective control.

8. Referring to the company mentioned in question 7, list the data which would have to be considered in determining the "economical run" for any given commodity, and indicate how you would use these data in arriving at proper conclusions.

9. What is the purpose of inspections of inbound shipments of materials? What particular interests within the organization must be served by these inspections? Who, in your opinion, should be responsible for this phase of inspection work. Why?

10. What is to be gained by centralizing responsibility for material stores? What do you understand to be meant by the statement that "centralized storeroom performance is seldom possible in a large plant but centralized control is always possible and should be insisted upon under all circumstances"? Do you believe this to be true?

11. Referring to question 7, assume that all these commodities are stored in one large storeroom. Consider the problem of storeroom arrangement required to facilitate the filling of requisitions, and draw up instructions which you think would adequately cover the situation.

12. What do you understand to be implied by the statement that "the balance-of-stores record should be 'tied in' with the general ledger records of the accounting department"? Explain how you would effect this "tie-in."

Do you think this record should be kept by the production department? Why or why not?

13. If a balance-of-stores record is kept, do you think it is necessary to continue to take a periodical inventory of the storerooms? Discuss.

14. The X Company has, for a number of years, followed the practice of making a very careful examination annually of all materials in stores, and it has been stated that this procedure has been very valuable in bringing to light inactive stores which should be disposed of and dropped from the inventory lists of the company.

Draw up a form of report which might be used in recording the results of such an investigation; indicate how each item of information shown thereon may be obtained and what use might be made of it. Indicate clearly how you would proceed with such an investigation.

15. The Mandel Pharmaceutical Company has found it necessary to keep in storage numerous materials which are subject to deterioration if kept too long. These are stored in porcelain-lined containers from which quantities are withdrawn

as required by the production department. Since there is usually some materials still on hand when a new supply is received, it has frequently happened that the old supply has been allowed to remain in the bin until it has become unfit for use.

Suggest a method which will insure that all materials will be used in the order they are received.

16. The Arden Packing Company has three boiler-rooms in different parts of its plant, each of which is a large consumer of coal. Space is provided at each for some storage, but it is the practice to keep these reserve supplies at a minimum and arrange for delivery as needed.

Give consideration to the problem of controlling this item of inventory, taking into account such questions as the following:

a) Is a perpetual inventory record desirable in this case?

b) Who should be responsible for seeing that deliveries are made as needed?

c) What factors should be considered in determining how much coal to hold as a reserve supply?

EXERCISE X—1

Design a complete set of standard forms to accompany the inventory-control procedures described at the end of chapter x. Draw up a chart showing the department originating each of these forms, the number of copies required, and the disposition to be made of each copy.

EXERCISE X—2

Conduct an original field investigation in some manufacturing organization (you may use the same company which you considered in Exercise IX—1 if you desire), and draw up a brief but comprehensive report describing their inventory control procedures. (The length of this report will, of course, depend upon the nature of the organization under investigation.) Examine these procedures critically and recommend any changes which you think should be made.

EXERCISE X—3

The Elwell Machine Company uses, in connection with one of its products, a small drop forging which it purchases according to its own specifications from a metal-working plant in a neighboring city. These forgings are delivered in lots and held in stores to be issued to the production department as needed. Standard inventory quantities are determined in advance for each commodity which is carried in stock, and the balance-of-stores clerk is authorized to issue a purchase requisition for a standard order of any commodity whenever the balance as shown in the stores record indicates that the ordering-point has been reached.

The quantity standards which are established in each case are as follows:

"Maximum"—representing the maximum quantity which will under any circumstances be on hands at any given time.

"Minimum"—representing the minimum amount which under normal conditions will ever be on hands at any given time.

"Ordering-point"—representing the balance on hand when a new order must be

"Standard order"—representing the standard quantity for which a requisition is to be placed whenever the stock on hand requires replenishing.

The commodity in question has never been used before, and it is accordingly necessary at the present time to establish suitable quantity standards governing its purchase. An investigation has been made, and the following facts have been established:

Time required to fill an order after placing it	10 days
Estimated maximum requirements during any 10-day period	450 units
Estimated minimum requirements during any 10-day period	100 units
Estimated annual requirements based upon a working year of 300 days	10,000 units

The purchasing department has made inquiries and finds that a contract can be secured at the following prices depending upon the quantities ordered at a given time:

Size of Order	Unit Price Quoted
600 units	$1.10
1,000 units	1.00
2,500 units	0.95
5,000 units and over	0.92

The cost department, also, has made certain calculations, and estimates that various items as follows should be considered:

Average cost of handling a purchase order regardless of quantity	$5.00
Storage costs for the commodity in question	25 cents per unit per year for the average inventory
Carrying charges, including interest on investment, insurance, etc.	10 per cent of the value of the average annual inventory should be allowed.

Assuming that the commodity in question will be required at a reasonably regular rate throughout the year, in what quantities should it be purchased in order to secure the year's requirements at minimum cost?

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QUESTIONS FOR CLASS DISCUSSION

1. Distinguish between job standards and standards of performance. Assume you have been asked to draw up job standards for some factory operation with which you are familiar. Enumerate the various factors which you would have to consider in formulating such a standard.

2. Distinguish between standards of method and standards of accomplishment. Why are these two types of standards so intimately related?

3. Is it true that in considering one kind of operating standard all kinds of such standards must be considered? Why or why not?

4. Do you think that management should assume full responsibility for the choice of methods in factory operations? Have changed conditions made this question more vital than formerly? Discuss.

5. Considering the question strictly from the worker's point of view, do you think it desirable that the choice of methods shall be regarded as the prerogative of management?

6. It has been suggested that job and method standardization are important chiefly because they are prerequisites for determining standards of accomplishment. Why are the latter so important?

7. Even though the job and the method be standardized, is it not so that we cannot standardize accomplishment unless the workman also is standardized? Can he be standardized? If not, how can uniformity of accomplishment be secured?

8. Do you think it a fair criticism of scientific management that it makes provision only for the best men in industry at the expense of the unfit? Discuss.

9. In connection with quality standards we have seen that they could be maintained only by providing adequate inspection facilities. Suggest means whereby we may be assured that job and performance standards will be maintained. Illustrate your answer by concrete examples.

10. In Taylor's day it was common practice for shop workmen to provide their own tools, take care of their own machines, etc. He maintained, however, that this was wrong and insisted upon the setting up of toolrooms and maintenance departments instead. Do you think these changes which have been quite generally adopted by industry were merely incidentals, or were they vitally related to the system which he sought to establish?

11. In a recent discussion of the question as to whom should be responsible for time and motion studies, the following suggestions were made:

a) The personnel department.

b) The production-planning department.

c) The engineering department.

Whom do you think should be responsible, and why?

12. In a certain machine shop twenty workmen are employed at identical machines in performing identical jobs.

Assume you have been asked to make a time and motion study of the operation. Make any assumptions you think are necessary, and draw up a program indicating how you would proceed, giving attention to each of the following points:

a) Preparatory considerations, including choice of worker to be observed, etc.

b) Method of recording observations.

c) Method of using the data you have recorded in establishing time standards for the job.

13. What do you think is the significance of the following statement? "Studies must be made of the time elements of each operation, divided into small enough units to be utilized in various combinations."

14. Keeping in mind that a time-study observation is essentially a process of sampling, enumerate the various factors which you think will have an important bearing upon the question as to how many observations of a given operation it will be necessary to record in order to provide sufficient data on which to base a satisfactory time standard.

15. Assume that you have been given a time-study observation sheet in which

the operation under observation has been divided into ten elementary operations each of which has been timed fifty different times. Enumerate the various statistical methods you might employ in establishing a norm for each element, and indicate what seem to you to be the relative merits of each method under the circumstances.

16. What is the purpose of time-study allowances? For what sorts of possible delays would you make provision, assuming that the standard you are attempting to establish is to be used as a basis for setting piece rates?

17. The assumption that one may make an accurate allowance for factors not included in the time-study observation record implies that the influence of such factors upon performance can be measured. Consider the various factors which were discussed in question 16, and indicate how you would proceed in attempting to measure their influence.

18. What special difficulties do you see in any attempt to measure the effect of fatigue upon performance?

19. One method of measuring fatigue which has been proposed is known as the "vascular skin reaction test." This test, according to published accounts, "consists in making a stroke on the surface of the forearm of the worker with a blunt instrument so devised that the stroke can always be made with the same pressure. The white streak which results from this stroke is studied with regard to its latent period, the time required to reach its maximum intensity, and the time at which it begins to spread and fade."

Upon what assumptions does the accuracy of this method of indirect measurement depend?

How would you attempt to discover whether this phenomenon was a real measure of fatigue?

20. Rest periods have sometimes been introduced in industrial plants apparently on the assumption that the retarding effects of fatigue may be forestalled thereby, and hence no further allowances in the standard of accomplishment for this cause will need to be made.

Enumerate the various kinds of rest periods which might be introduced, and give your opinion as to their probable utility for this purpose.

How would you determine the length and frequency of rest periods to be allowed on a given job?

21. From your study and observation of the results of time-and-motion-study work, do you think that the introduction of this technique has made substantial contributions to the efficiency of production operations?

22. How do you account for the rather general antagonism of organized labor (at least in the past) to the introduction of time-study methods?

23. In these criticisms do you see evidence of objection to the method itself, or are they chiefly a protest against the unintelligent, and sometimes unscrupulous, use made of the method by management?

24. Do you think that time and motion study will supply information concerning time of performance which is any more accurate or useful than that which could be obtained by a careful analysis of past performance in the shop?

Would not such a study of past performance render time-and-motion-study work unnecessary?

25. The manager of the X Manufacturing Company, while recognizing the desirability of accurate information concerning operating times for various jobs, contends that the way to secure this information is to assign one of the best workmen to the job and allow him sufficient time for experimentation, while actually performing the task, to determine the best method and the time which should reasonably be allowed for performance.

What do you think of this method?

26. Do you think standards of accomplishment could be established and insisted upon for clerical workers? for research workers? for designers? for inspectors? for executives? Why or why not in each case? If not, how can you measure the performance of such workers?

EXERCISE XI—1

Conduct an original investigation in some plant in which the management has had experience with time-and-motion-study work, and write a short report giving attention to such points as the following:

a) Use made of time standards.

b) Method used in establishing same. In describing these you should give careful attention to the various details which have been suggested by your study of this subject.

c) Opinion of the management with respect to the utility of such work.

d) Your criticisms of the work and suggestions for improvement, if any.

EXERCISE XI—2

The Chalmers Machine Corporation, which was founded in 1909 for the purpose of manufacturing a patented road-grader, is today one of the leading producers of heavy construction machinery, manufacturing and distributing a complete line of general contractor's equipment, including concrete mixers, excavating and grading machinery, steam shovels, heavy dump trucks, tractors, and trailers. Since 1920 it has grown steadily, until today it employs approximately 3,700 men in its main plant, not including general office employees and selling forces who are located in the down-town district of a large mid-western city some 30 miles from the plant.

The plant is well located, well built, and modern in every respect, and the product enjoys an enviable reputation in the trade. The general plan of plant layout within the several departments is, for the most part, according to types of machines, though the departments themselves are organized in conformity with usual practice according to operations. These departments, together with a classification of the various grades and numbers of employees, including skilled, semiskilled, and unskilled labor, are as follows:

1. Foundry
   - 20 Patternmakers
   - 45 Core-makers
   - 70 Molders
   - 55 Chippers and finishers
   - 40 Yardmen
   - 10 Crane operators
   - 5 Inspectors and supervisors
   - ——
   - 245 *Total*

2. Forge shop
   - 20 Forgemen
   - 45 Helpers
   - 35 Heat-treatment operators
   - 85 Material-handlers
   - 10 Inspectors and supervisors

   195 *Total*

3. Frame department
   - 50 Drill and press operators
   - 70 Riveters
   - 5 Crane men
   - 90 Material-handlers
   - 8 Inspectors and supervisors

   223 *Total*

4. Plate shop
   - 110 Drill and press operators
   - 50 Riveters and welders
   - 10 Crane men
   - 130 Material-handlers
   - 15 Inspectors and supervisors

   315 *Total*

5. Wheel shop
   - 40 Drill and press operators
   - 18 Riveters
   - 12 Welders
   - 110 Material-handlers
   - 5 Inspectors and supervisors

   185 *Total*

6. Machine shop
   - 140 Punch-press operators
   - 110 Drill-press operators
   - 85 Lathe operators
   - 75 Milling-machine operators
   - 90 Auto, screw, and gear cutting-machine operators
   - 110 Grinders and finishers
   - 210 Material-handlers
   - 70 Bench workers
   - 50 Heat-treatment operators
   - 35 Inspectors and supervisors

   975 *Total*

7. Erection shop
   - 125 General mechanics
   - 200 Helpers
   - 30 Crane men
   - 190 Material-handlers
   - 50 Painters
   - 15 Inspectors and supervisors

   610 *Total*

8. Carpenter shop
   - 15 Machine operators
   - 25 Bench men
   - 85 Erection helpers
   - 10 Crane men
   - 50 Material-handlers
   - 55 Painters
   - 12 Inspectors and supervisors

   252 *Total*

9. Assembly department
   - 30 General mechanics
   - 40 Helpers
   - 5 Crane men
   - 60 Material-handlers
   - 20 Painters
   - 4 Inspectors and supervisors

   159 *Total*

10. Stores department
    - 70 Yard men
    - 10 Crane men
    - 14 Clerical workers
    - 4 Supervisors

    93 *Total*

11 Shipping department
   - 55 Box carpenters
   - 10 Crane men
   - 50 Material-handlers
   - 7 Clerks
   - 1 Supervisor

   123 *Total*

12. Miscellaneous employees
    - 85 General clerical workers
    - 15 Designers
    - 45 Draftsmen
    - 35 Toolroom employees
    - 55 Toolmakers
    - 15 General supervisors
    - 10 Millwrights and electricians
    - 40 General maintenance men

    300 *Total*

Grand total, 3,675

The general plan of organization within the plant has not changed materially with the growth of the organization, it being characterized by extreme decentralization with the foreman occupying a key position of great importance. A general foreman reporting directly to the production manager is in charge of each general department. To each of these general foremen report a number of shop foremen, each of whom is responsible for one general class of workers, as shown, within his own department. In some departments these foremen are in turn aided by assistant foremen, checkers, inspectors, and timekeepers, as required depending upon the number of workmen under their direct supervision.

During the last few years, expansion has been very rapid, and profits have for the most part been very satisfactory. Recently, however, the company has become involved in certain difficulties which, in conjunction with the retirement of the general manager, who has been with the company since the beginning, and the selection of a new chief executive have led the company's bankers to advise a recasting of the internal organization of the company. The production manager is a very able engineer whose technical skill, it is believed, has been a very important factor in the company's success. He has not demonstrated great ability in dealing with problems of organization; but his great technical ability, together with the fact that he is an important stockholder in the company, precludes the possibility of dispensing with his services. He recognizes, as well as anyone, his particular weaknesses and has proposed that an assistant production manager be secured who will assume the chief burdens of reorganization and management within the plant, thus allowing the production manager himself to follow his natural bent in connection with the technical aspects of production. As a possible candidate for such a position there is already in the plant organization a young man who has shown marked ability in dealing with organization matters and has demonstrated that he has the necessary tact and forcefulness to undertake the task of reorganization. This man has just recently succeeded in centralizing control of production-planning activities in the plant which hitherto had been largely left to the general foremen within their respective departments. These changes have not been effected without encountering strong opposition from some of these foremen who felt that they were being deprived of authority which rightly belonged to them, but the task has been conducted with such skill that they are now reconciled to the change and solidly behind the undertaking. Credit for this is largely due to this man, who enjoys the entire confidence of the production manager; and it has been definitely decided that he is the logical man for the new position.

A preliminary survey of the organization has revealed that many matters for which control is usually centralized in a plant of this size are left to the individual foremen in their respective spheres. Each foreman, for example, has complete control of all manufacturing operations in his own department, with the exception of production planning, as already mentioned. In addition to immediate direction of the work of the shop, he supervises inspection, material-handling, and employee relations, including selection and hiring of workmen, training, setting of wage rates (approximately two-thirds of the workers are on piece rate, the remainder being on straight-time pay), firing, and matters of discipline. General wage scales are de-

termined by the general foremen in conference with the production manager, but all details arising in administering the piece-rate system are settled independently by the general foreman in conference with the shop foremen under their supervision.

With respect to employment, the production-planning department has been in the habit of notifying each department head, as far in advance as possible, the amount of work on schedule in his department; and the problem of securing an adequate labor supply for accomplishing the work on schedule has been left to be solved by him and the foremen directly under him. When workers of a certain grade are needed, he notifies the central office; and word is sent out through various channels that workers of that particular grade are being employed. The general foreman or his assistants then go to the gate and select from those presenting themselves for employment the men who, after preliminary questioning, appear to meet their requirements. The timekeeping department is notified that they should be placed on the pay-roll, and they are put to work without further ceremony. Should the workers thus selected not prove satisfactory, they are as unceremoniously discharged, quite frequently only again to appear for rehiring by another department at some later date. Indeed, it has been found that often certain workers have been hired and discharged by several foremen several times without anyone being the wiser.

All of the usual charges of favoritism, of placing friends and relatives in soft jobs, and of preference for workers of the same nationality and religious faith as the foremen, which customarily arise where foremen are given such wide discretion, have been prevalent and have tended to break down morale; and the methods in vogue have, it is believed, been the cause of an unusually high labor turnover, though no definite records concerning such matters are available.

The new assistant manager is convinced that many radical changes in management should be made, and has voiced the opinion that the remedy lies in effecting much greater centralization of control than now exists. He has asked you, as an outsider trained in dealing with such problems, to consider the situation carefully and prepare a report, giving your tentative recommendations as to what you think should be done with respect to inspection and employee relations in particular, indicating as clearly as you can, without further investigation at this time, what measures and special problems would likely be involved in putting your recommendations into effect.

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QUESTIONS FOR CLASS DISCUSSION IN CONNECTION WITH CHAPTER XII

1. It has been suggested that many obscurities in the literature of business organization are caused by a lack of standard terminology. Can you cite instances where various terms commonly employed in discussions of organization have been used in different ways by different writers?

2. How would you (or *would* you) differentiate between organization and administration? between management and administration?

3. In what essentials do executive activities differ from non-executive activities? Be prepared to defend your answer.

4. Organization is sometimes used in referring to the form of the business unit. In other instances it is employed when referring to the internal structure of the unit. Cite illustrations of these two common forms of usage. Are they in any way related?

5. Which of the following quotations, in your opinion, represents the correct method of procedure in building an organization?

"Shape the man to the organization rather than the organization to the man."

"In setting up an organization it is necessary to recognize these weaknesses [weaknesses of available personnel] and vary the type of organization so that you may take advantage of the strong points of an individual and at the same time protect yourself from his weaknesses."

Reconcile these statements, if they can be reconciled.

6. Cite illustrations in support or disproof of the following statement: "Organizations differ not so much because each has a different set of activities to perform as because these activities vary in relative importance under different circumstances."

7. How would you distinguish between a "chart of activities" and an "organization chart"? Might it be desirable in a given organization to give consideration to constructing both types of chart?

8. One authority mentions the following "types" of organization: (1) line, (2) line and staff, (3) functional, (4) committee. Distinguish between these various types and state your opinion concerning the adequacy of this classification.

9. Assume you have been assigned 5,000 men and the necessary equipment and have been given complete responsibility for clearing the streets of a large metropolitan area after a heavy snowstorm. Outline the various ways in which you might organize your forces for doing the job, and indicate what, in your opinion, would be the relative merits of the various methods.

10. The X Manufacturing Company employs approximately 1,000 men in one shift in one of its shops. It has been decided to employ another shift in three departments, which will necessitate adding approximately 500 more workmen to the pay-roll. What changes in organization do you think will likely prove necessary in order to provide for this change?

11. Under what general conditions might activities be organized on a territorial basis?

It has been suggested that this basis implies some form of territorial specialization. Why is territorial specialization necessary? Use concrete illustrations in an-

Do you think this basis of departmentation is applicable in the production department as often as in other departments?

12. Referring to the "gang" method of organization described in this chapter, what specific considerations would have to be taken into account when deciding how large the individual gang should be?

Do similar considerations govern the size of a territorial department?

13. Cite illustrations of the so-called "customer and commodity bases of departmentation." Do you think either of these bases is applicable in the production department? Why or why not?

14. What is a function? Specifically, how would you determine what activities to include within a given functional department?

15. It has been suggested that Taylor and perhaps Church and Sheldon have used the term "function" in a somewhat different sense than have McKinsey, Briscoe, and Robinson, as well as a number of other writers. Distinguish clearly between these two views. Do you think that both types of functional departments might be used in a given organization at the same time? Discuss.

16. Explain and discuss Taylor's plan of organization known as "functional foremanship."

Do you think this plan of organization could be applied throughout an organization? Why or why not?

Has it any practical significance?

17. Distinguish between "line" authority and "functional" authority, concretely illustrating your answer.

With reference to Taylor's plan of functional foremanship, of what significance is it that he apparently recognized the existence of only one kind of authority?

18. It has been contended that the functional foremanship scheme is impractical because it makes it necessary for the workman to serve more than one boss. Why cannot a workman serve more than one boss, assuming that he cannot? Would it not be possible for him to do so under certain conditions? What conditions, for instance?

19. One of the characteristics of a good organization, it has been suggested, is a clear definition of all lines of authority so that each worker may know what his several duties and responsibilities are. Suppose you were called upon to develop an organization for a new manufacturing enterprise. What steps would you take, and what devices would you use in order to insure this result?

20. In many organizations, such as railway and industrial companies for instance, in which operations extend over a wide territory, major executives often find it necessary to spend much of their time away from their offices; and under such circumstances it sometimes develops that much work of a semi-executive nature is delegated to a chief clerk. The chief clerk usually has no recognized line authority and issues orders only in the name of his chief. More often than not he is not fitted by training or personality for promotion and consequently tends to be a fixture in the office, becoming well nigh indispensable to each new administration because of his knowledge of the traditions and the routine of the department. Long experience is likely to make him expert in keeping himself "in the clear" and in

avoiding responsibility, and thus in many instances he is heartily disliked by junior executives who resent his arbitrary assumption of authority but who, nevertheless, are reluctant to register a complaint with his superior because of the recognized dependence of the latter upon him to assume the burden of routine administration. As a result, the chief clerk has often come to occupy a position of authority out of all proportion with his direct responsibility, and to exert an irritating influence which is detrimental to the morale of the organization.

What are the chief weaknesses of such a method of organization, and what suggestions as to possible alternatives can you make?

21. What do you consider to be the function and sphere of committees as an organization device?

Suggest concrete instances where you think a committee can be used to good advantage, and indicate why you think so.

22. In a certain organization the policy has been adopted of requiring everyone to have an understudy, and it is understood that no one can be considered in line for promotion until he can demonstrate that his present position can be filled by the man under him. A chart showing the various lines of promotion throughout the organization has been worked out, and wherever possible this scheme is adhered to when vacancies occur.

In another organization it has been the custom each year or so to select a small group of likely young men, either from among the company's existing personnel or from the outside, who bear evidence of superior potential executive ability. The president of the company has himself devoted considerable attention to the selection of the group, which has come to be known throughout the organization as "the officers training camp." Every opportunity for development through contact with executives and a variety of experience is afforded this hand-picked group with the idea of pushing them on as rapidly as possible to positions of responsibility. While it is admitted that this forcing method does tend to arouse feelings of envy, discontent, and in some cases ill will among the less favored members of the organization, the president is heartily in favor of it since it enables capable young men to reach positions of responsibility while still retaining the fresh outlook and enthusiasms of youth. The traditional methods, he contends, too often needlessly expose an able man to years of heartbreaking routine only to bring him to a position where he may exercise his full powers at an age when his energies have begun to decline.

What do you think of the relative merits of the methods used in these two organizations for discovering and developing executive talent?

Do you think the seniority rule should be given any weight when determining promotions?

23. Is not something to be gained by bringing in outsiders to fill important executive positions in an organization? Discuss.

24. Recently it was discovered that in a certain large manufacturing organization the executive in charge of production had between fifty and sixty junior executives reporting directly to him. When questioned as to the wisdom of this plan of organization, he stated that he expected and received the full measure of loyalty from each of his men and that whenever he found that this was no longer possible in any

case the offending subordinate was replaced. In return for this whole-hearted co-operation, he felt that he owed it to his men to be in direct contact with as many as possible. He regarded his function to be chiefly one of maintaining the morale of the junior executives, who, in any event, must assume the chief burden of performance. He further stated that experience had taught him that the best way to maintain morale was to invite personal contact. He accordingly gave each subordinate full responsibility and authority in his department, and for his own part spent practically his entire working day in conference with the various members of his staff of subordinates in which any subject which they wished to discuss was freely considered. He stated that, as far as he was concerned, he would strenuously object to any plan of organization which would tend to discourage such personal contacts.

In view of the fact that apparently the morale and efficiency of the department were very high, do you think it could be contended that this was not good organization?

25. Cite as many applications as you can of the principle of checks and balances in business organization.

Might not too strict insistence upon this idea lead to ineffective management? Discuss.

26. In the light of your study of organization thus far, do you think there is any possibility of developing a science of organization? Discuss.

27. Do you think there is any place in the business community for a professional group of councilors upon matters of business organization?

28. We often hear it said of an outstanding business executive that he is a genius in business organization. What seem to you to be the most important elements in the special skill displayed by such favored and much sought-after individuals?

QUESTIONS FOR CLASS DISCUSSION IN CONNECTION WITH CHAPTER XIII

1. Prepare a statement giving your opinion as to the proper scope of activities of the production department.

Do you think it is possible to prepare such a statement which will apply equally well to all manufacturing enterprises? Why or why not? What factors will have to be considered when deciding what activities to include within the jurisdiction of the production manager? Cite concrete illustrations to support your views.

2. It is sometimes contended that there should be some major department within every organization to which should be delegated responsibility for specifying the standards and procedures to be used by the various departments throughout the organization. Do you see any reason for this contention?

Would you give such a department responsibility for product and raw-material standards? for machine and plant environmental standards? for standards of accomplishment? for production-planning procedures? for inventory-control procedures? for shop instructions? for inspection procedures?

Justify your views in each of these instances.

3. Assume that one of the major executives of the business is a controller who,

among other things, is responsible, let us assume, for accounting, statistics, budgetary control, and office management.

Indicate clearly your views as to the extent and nature of the authority he should exercise in the production department.

4. Outline clearly your opinion with respect to the relationship and division of responsibility and performance which should exist between the production and the purchasing departments; between the production and the accounting departments; between the production and the personnel departments. Be prepared to defend your views.

5. In this chapter a chart of activities was shown suggesting a possible scheme of functional departmentation of production activities. Assuming, for the time being at least, that the plan is a plausible one, and keeping in mind that a functional organization is usually defined as one in which similar or allied activities are grouped together in separate departments, consider this scheme with the purpose of determining the apparent basis of similarity in each case. Make any criticisms you think should be made, but be prepared to defend your contentions.

6. Do you see any justification for placing store-keeping under the production manager?

7. Are you able to discover any evidences of blood-relationship between the proposed organization of production planning and operating activities and Taylor's scheme of functional foremanship?

8. State your opinion concerning the specific activities which it has been suggested might be placed in the production-planning department. Are there any other activities which you think might well be placed in this department? Why?

9. Which of the activities shown in the chart referred to have, as their purpose, the evaluation and measurement of production performance?

Are there any other activities of similar function which have not been included in this classification?

If so, can you see any reasons why these specific activities should or should not be placed under the authority of the production manager?

10. Do you see any particular advantages (*a*) in distinguishing between manufacturing services and manufacturing processes? (*b*) in grouping all manufacturing services under one central control?

11. In the proposed chart of activities no avowed attempt has been made to provide for separation of shop and office activities.

Do you think such a separation might properly be attempted?

Which of the proposed departments would be principally office departments? Which principally shop departments?

Do you think it would be practicable to set up a central bureau of filing and records and perhaps a central stenographic office for the department?

12. Cite as many instances as you can in which you feel that the commodity basis of departmentation might properly be employed in organizing production activities.

13. Consider the chart of activities which has been discussed in the foregoing questions from the point of view of its adequacy and applicability in an enterprise

manufacturing a single standardized commodity on a continuous basis, such as a flour mill or a cement plant, for example.

Make whatever revisions you think would be desirable under such circumances.

EXERCISE XIII—1

The Nelson Steel Foundry Company is a large manufacturer of railway supplies employing approximately 4,500 men in a plant which covers about 18 acres in a manufacturing district of a large city. Its products are composed entirely of iron and steel, which is purchased in the form of pig and scrap iron with the exception of small standard parts such as bolts, nuts, bar iron, etc., which are procured in finished form. The raw material is converted into iron and steel castings and steel forgings, which are in turn machined and assembled in the finished products.

The company has found it desirable to develop its own water supply, which is pumped from an adjacent river to a large overhead tank. A power-house is provided which generates steam for driving turbo-generators which produce electric current. Special steam pumping engines which use the exhaust steam of the turbines are employed for raising the water supply.

The product is varied, and the work performed is as follows: Iron castings are made from iron which is melted in a cupola furnace. Steel used in making castings and forgings is produced in an open-hearth furnace. Both of these furnaces are heated by gas from the company's own gas plant. Some of the company's products are made of high-grade alloy steels. These materials are produced in an electric furnace, the process employed being to withdraw metal from the open-hearth furnace when an advanced stage of manufacture has been reached, and to complete the operation in the electric furnace, which is much more expensive to operate but which affords greater control of the operation and hence a better grade of finished product. The alloy steel is all used in making castings.

All castings are molded on the same molding floor, and all patterns are prepared in the same pattern-shop. Many patterns are used only once and hence are made of wood. Patterns for standard castings are used for repeat orders and usually are made of metal.

All castings are cleaned and finished in the same finishing department adjoining the foundry. An annealing process is used for some castings but not for all, and the annealing and finishing processes are located in the same building under the same man's supervision.

All castings and forgings are machined; and most shipments consist of an assembled product, although many individual parts are sent out as repairs. Some of the equipment manufactured is of standard design; but fully 75 per cent of the total product is manufactured subject to purchaser's specifications, and all of the product is manufactured on a job-order basis. The purchaser usually submits plans covering the general design required, but not always; and in any case, it is necessary to prepare shop drawings in the company's own engineering office.

All materials are purchased in a central purchasing department, which is also responsible for raw-material stores. Receiving and shipping is supervised by the

traffic department, the head of which reports directly to the general manager. All foremen have in the past been permitted to hire all help required in their own departments, although there is a personnel manager who exercises general supervision over labor policies, and rate setting, negotiates labor contracts, etc. The cost department and the production-planning office are located in the same building in the plant and are under the same supervision. General accounting for the company is supervised by the general auditor, whose office, along with those of other general executives of the company, is located in the down-town business district.

Draw up an organization chart for the production department of this company and prepare a statement making any suggestions as to changes which you think may be advisable under the circumstances.

EXERCISE XIII—2

Continue your investigation begun in some company in connection with one of the exercises assigned in previous chapters, and draw up an organization chart for the production department of the company. Prepare a report to accompany this chart, giving your criticisms and suggestions for possible changes in organization which you think might prove desirable.

EXERCISE XIII—3

The Pierce Well Works of St. Louis was founded in 1900 by Alfred Pierce, a widely experienced engineer, for the production, under his own patents, of an impeller pump designed for use in shallow wells of large capacity.

The new product won great favor with municipal water plants throughout the prairie belt, and the enterprise quickly passed the experimental stage. In 1906, a partnership was formed with James Jackson, a man of considerable selling experience, and shortly afterward a wind motor with steel tower and a line of deep-well pumps suitable for the western farmer market were added.

Under the guidance of the new sales manager the products soon became popular, and a period of rapid expansion followed. With the opening of the southwestern oil fields on a large scale, a line of drilling and fishing tools was added, and the firm's growing engineering force developed a superior type of centrifugal pump.

In order to provide for necessary expansion to handle this growing list of products adequately and to develop a suitable market the partnership assets were turned over to a newly organized corporation with a capital of $500,000, in 1915. The founder became president of the new company and retained direct charge of the production department, and the junior partner became vice-president and responsible head of the sales department. Otherwise the organization remained much the same as before except that a local banker, who had aided in forming the company, assumed the office of treasurer. The plant auditor, while nominally reporting to the treasurer, continued to have active charge of the office much as before the reorganization. No other important changes in organization were made.

By virtue of very profitable contracts with several oil development companies the company prospered greatly during the war period, and a considerable surplus was built up, more than doubling the net worth of the company. In 1918 the board

of directors felt justified, on the strength of past earnings and prospective sales, in making extensive additions to the existing plant; and after consultation with advising bankers, voted to offer $1,000,000 of five year, 7½ per cent notes secured by a mortgage on the property. The company was able to present very attractive financial statements and prospective sales contracts, and the issue was sold within a short time at par, the proceeds all going into new additions to plant.

After 1920, however, curtailment of oil-well development led to cancellation of advantageous sales agreements, and a series of lean years served to dissipate much of the company's surplus although the sales department, by dint of much hard work, succeeded in maintaining sales with no perceptible falling off. As a result, when the note issue came due late in 1923, the company was not in a position advantageously to refund. The president and leading stockholder, being quite old and feeling unequal to the task of financial rehabilitation, was willing to resign and, in consultation with a creditors committee, agreed to a reorganization. An official of a competing company was secured as president, and a firm of professional business councilors was retained to make an investigation and offer recommendations as to what should be done to place the company on a sound basis. The following facts are abstracted from the report of this firm which was submitted at the time:

One serious deficiency, it was found, was the fact that little was known concerning the costs of production. The plant auditor had grown up with the company and was chiefly interested in the general accounts required to facilitate the preparation of financial statements. He had shown little interest in developing cost analyses, and indeed had received little encouragement from the old régime to do so. Some forward-looking foremen had kept some fragmentary records in their own departments for their own use, and the engineering department had compiled considerable "cost data" as an aid in design and the placing of bids; but further than this there were no facilities for the determination of current unit costs. Sales had been greatly expanded in pump lines which, it was felt, were being manufactured and sold on an unsatisfactory margin. This could not be definitely determined, however, until adequate information was available.

An analysis of the manufacturing problems of the company revealed that the product was all exceptionally well designed and fully capable of competing with other lines in the field. The plant was modern and well equipped, although it was felt that many economies could be effected, without too great derangement of existing facilities, by a more pronounced departmentation according to operations and processes. This would enable the fixing of responsibility with greater ease. A fairly efficient production-planning control had been developed by a staff assistant of the production manager; but little evidence of efficient control of stores was discovered, a fact which had apparently been responsible for considerable waste.

An examination of the various products revealed the following:

Impeller Pumps: Built in two sizes, always on special order, from stock and special parts including light forgings, phosphor-bronze and steel castings. Their manufacture involved light and heavy machining of parts as well as assembly in the factory and erection in the field. The sales price of these units always included the designing and installation charges by the company's own engineering forces. These

pumps were equipped for direct-connected vertical electrical motors. The motor was never furnished by this concern, though technical advice was given concerning same and the erection forces usually supervised the installation without extra charge.

Oil-Well Drilling Tools: Consisting of a line of fifteen varieties, always sold from assembled stock. An attempt was made to ship these goods immediately upon receipt of order, but this had not always been possible during the busy season. The manufacturing processes involved heavy forging from steel billets, tempering of cutting edges by a special process, heavy machining work, and assembly.

Windmills: One kind sold in three sizes ("A," "B," and "C,") from stock only. Tower steel was purchased in the form of angle and bar galvanized stock in commercial lengths, and was worked by means of cutting, punching, welding, and assembly, in a special department in the company shops. Part of the small motor parts consisting of malleable castings were purchased in the rough under a contract with an adjacent foundry and were machined and assembled in the company plant. Some parts were purchased in finished form ready for assembly.

Deep-Well Pumps: The manufacture of small deep-well pumps was discontinued in 1916, but a line suitable for use with the wind motor was purchased from a company specializing in light pumps and was carried in stock for the convenience of dealers.

Centrifugal Pumps: Carried in three sizes (three-, six-, and ten-inch) and also built to order for large special installations. Manufacturing consisted of heavy casting and forging and both light and heavy machine work. Special brass bushings and mountings were purchased in finished form in accordance with company specifications. For stock models these brasses were carried in stock, but for special models it was necessary for the most part to secure them on special order. The special models always required special designing, preliminary study of requirements, and expert installation by company engineers. These pumps (both special and standard models) were designed either for belt-drive or direct-motor connections. Where motors were specified, it was the custom to purchase them complete from a large manufacturer of stock motors and furnish them to the customer at cost.

Repair and Replacement Parts: Parts for all stock products were supplied to former customers, being shipped direct from stock as soon as ordered, and for special machines were manufactured upon request.

The sales policies were found to be as follows:

The impeller pumps which found their principal market with municipal and large institutional water plants were sold through the company's traveling representative, the nature of the work requiring special technical training since he frequently was required to act in an advisory capacity and to make preliminary designs. The oil-well supplies were sold only under blanket contracts to oil development companies, the contracts in each case being drawn up and negotiated by Mr. Jackson in person. Two special field representatives were employed, however, for the purpose of calling on the trade and rendering technical advice and assistance to past customers as required. The windmill and deep-well pump line was handled

only through manufacturer's agents. There had been, it was found, some tendency during the preceding five years to neglect this line, which at the time amounted to only 5 per cent of the total business of the company. An analysis of the sales of the year just preceding, however, showed that interest in the line was reviving, and it was thought that sales in the future would probably be of greater volume than in the past. The centrifugal pumps were sold direct to users by catalogue description or after inspection on the company's sales floor maintained for this line in the downtown district. The special installations were sold only on the basis of competitive bids involving the submission of plans and specifications by the company and always requiring considerable preliminary investigation whether the job was later secured or not. Since 1920 an enviable reputation for jobs of this kind had been acquired, and this item, at the time of the report, amounted to over 50 per cent of total sales, which were approximately 7 million dollars annually.

As a result of this investigation, it was decided to reorganize with an authorized capitalization of 5 million dollars. The shares of the old company were exchanged for new shares, and sufficient additional shares were sold on the open market to retire the outstanding indebtedness and raise $500,000 additional capital. A new vice-president to take charge of production and a controller were secured. The former assistant production manager who had been in responsible charge of purchasing was retained in that capacity, but henceforth was made directly responsible to the president. This man was also given direct responsibility for the stores department, and other minor changes in the organization of the production department were made in accordance with recommendations contained in the report.

No new developments involving important changes in organization, except the discontinuance of the windmill and deep-well pump lines in 1925, occurred until 1927, in which year, through certain financial arrangements, the company secured a controlling interest in a progressive electric supply manufacturing company with a plant in Milwaukee, Wisconsin. The latter company specialized in the manufacture of motors and had succeeded in building up an attractive business in small electric generating units and water-supply equipment which was in much demand for farm use. For a number of years the two companies had had close business relations, the Milwaukee plant supplying the former with motors as needed and in turn buying the pumps used with its product from the St. Louis company. These relations were the chief reason for the consolidation.

As a result, the executive officers, including the president, the controller, and the vice-president in charge of sales, were moved to Chicago. The vice-president of production remained in St. Louis as works manager. The president of the Milwaukee company retired, and a vice-president who had come up through the production department became plant manager at that location. The two plants continued, however, to be operated practically as separate concerns.

Recently an agreement has been arranged for the consolidation of this company, now known as the American Equipment Corporation, and the Caldwell Engineering Company of Cleveland, Ohio. The latter is an old and well-established builder of steam turbines, large pumps, and air-compressor equipment. The chief executives of the former will continue, it has been decided, in the same capacity in the new

company with offices in Chicago. It is planned, however, to effect a more centralized type of organization and to consolidate the varied operations of the company. The Cleveland plant will be used for the production of large special equipment for which it is particularly well equipped. The production of standardized air compressor equipment, which comprises the larger portion of this branch of the business, will henceforth be carried on in the St. Louis plant which will continue to manufacture oil-well supplies and standard centrifugal pumps as heretofore. The line of impeller pumps is to be discontinued. The Milwaukee plant will continue to specialize in the manufacture of farm generating and water-supply units, as well as stock motors for use with the other types of equipment manufactured by the company. A vice-president of production is to be secured who will be responsible for all production activities and will maintain an office at headquarters of the company.

1. What, in your opinion, are the most important organization problems which have been raised by the successive stages of development of this company as briefly described in the foregoing?

2. Draw up a tentative chart of activities which you think may adequately provide for the needs of the company resulting from this latest reorganization.

3. Suggest methods of dealing with the personnel issues raised by the last consolidation.

BIBLIOGRAPHY, QUESTIONS, AND EXERCISE FOR USE IN CONNECTION WITH CHAPTER XIV

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QUESTIONS FOR CLASS DISCUSSION

1. Outline in some detail what you conceive to be the meaning and purpose of budgetary control.

2. What similarities and differences in content and purpose do you see in the budgetary problems of the following types of enterprise?

   a) A governmental unit
   b) A university
   c) A department store
   d) A manufacturing business

3. Discuss the relation of the sales budget to the production budget; the relation of the production budget to the plant and equipment budget.

4. Wherein does the problem of budgeting production in a company manufacturing a completely standardized line of goods differ from that of a company of the special-order type manufacturing unstandardized products?

5. One of the most difficult problems of a manufacturing organization is that of regularizing production. How may a production budget be used in solving this problem?

6. The X Manufacturing Company has four factories located in different parts of the country. In what way does this affect the preparation and enforcement of the production budget?

7. In what respects does the problem of preparing the production budget in a continuous-process manufacturing plant differ from that in an intermittent-process plant?

8. Who, in your opinion, should be responsible for the preparation of the production budget? Give reasons.

9. The Simplex Manufacturing Company manufactures and sells wrenches, pliers, drills, dies, and other tools used by the building and construction trades. Approximately one-half of its line of products of this nature containing slightly more than 1,000 items are manufactured in its own plant. The remainder are purchased from other manufacturers according to rigid specifications and, like its own products, are sold through hardware jobbing and retail channels. Recently the company has acquired control of another concern, located near its own plant, which manufactures a high-grade line of builders' hardware. The combined sales of the two plants amounts to approximately 10 million dollars annually, and at present about 2,000 men are employed.

This company has never had an adequate budgeting system for its manufacturing operations, though a fairly detailed sales estimate has been made for some years past. The management desires to instal a more detailed method of budgeting production. Indicate in some detail just what will be involved in making such an installation, outlining the general types of budget estimates which will be required, the general procedures which you think should be observed in preparing such estimates, and how such a system of budgets may be used in controlling factory operations.

10. In installing budgetary systems, industrial engineers often find it necessary to give careful attention to organization and cost-accounting problems. Why is this likely to be the case?

11. Discuss the relation of budgeting procedures to the work of the production-planning department.

12. Enumerate the various factors which have bearing upon the length of the budget period to be adopted, and show just how each of these factors affect the decision to be made.

13. Suppose that the sales budget summary has been presented to you as production manager and that you find it calls for the production of more goods than can be supplied by your present plant facilities.

What questions would you raise and what investigation and lines of inquiry would you wish to have made before making your recommendations concerning the matter to the general manager?

What if the preliminary sales budget called for a production schedule of only one-half of the production operations of the previous period?

14. One of the arguments advanced in favor of a carefully prepared budget program is that it provides a definite standard by which to measure actual performance during the period. Indicate, as definitely as possible, just how it may be so used.

15. "One of the first things which must be definitely ascertained [in preparing a production budget] is the production capacity of the plant."

What factors determine the productive capacity of a plant?

How would you proceed to determine the productive capacity?

Of what significance are standards of performance in attempting to do so?

16. "When the production budget has been finally approved, it should be re-

shown in this chapter and suggest how the information contained therein might be shown in graphic form.

17. "Budgets should always be prepared in terms of units of responsibility." Just what does this mean in terms of the production budget?

EXERCISE XIV

The Turner Machine Company manufactures tools and equipment for the metal-working industries. Its average annual sales over a period of ten years have been approximately $2,000,000, though sales have fluctuated widely from year to year, ranging from over $5,000,000 in 1928 to less than $500,000 in 1930. Approximately two-thirds of the company's line of products consists of thirty-six standard-model machine tools, the remainder comprising special types of machines which must be built to special order. In designing machines of the latter type, the company's engineering forces always try to use standard parts wherever possible, and specialized manufacturing operations thus are confined within relatively narrow limits, the standard parts being drawn from the same stock regardless of whether they are to be used in special or standard assemblies. During the past few years the percentage of special orders has been on the increase, and it is expected that this tendency will continue in the future.

As indicated, the volume of sales fluctuates widely with varying business conditions and employment, and plant operating conditions have accordingly been very irregular. This is clearly recognized as one of the most serious problems of the company, and no very satisfactory solution has as yet been found. It is practically impossible to apply the usual remedy of producing stock in anticipation of needs during dull times on account of the rapid technical progress in the industry and the limited financial resources of the company. However, the sales department has succeeded in securing some new business consisting of the manufacture of various small metal parts for other companies, which has enabled the company to keep its foundry and part of its machine-shop running during several recent months of serious depression when otherwise its plant would have been completely shut down. A new product has also been developed which, it is believed, will have a much more stable market than is typical of the machine-tool business. This product has been given rigid operating tests, and it is hoped by the management that it will eventually find a stable market capable of absorbing as much as one-half of the total sales volume of the company, thereby providing more regular production than is now possible.

At the present time the production manager, who is also a vice-president and important stockholder of the company, which is entirely owned by three brothers, plans production operations and supervises the purchasing of all raw materials. A young man working under his direction has prepared tabulations of sales, month by month, for the principal lines of product for a number of past years, and from these tabulations has developed a series of curves which are assumed to represent the normal sales curves for the year. These are corrected for each year's experience, and these values are compared at the beginning of each month with the actual sales for that line for the month just closed. On the basis of these comparisons and the judgment and experience of the production manager, an estimate of the probable

production requirements for the following month is made. The content of this estimate is discussed with the sales manager; and if these two departments are found to be in substantial agreement, a schedule of production for the month is set up in accordance with these estimates and orders are initiated in the factory. It is maintained that no such estimates for special orders can be made, and in consequence nothing is done concerning such orders until sales contracts are secured. Such products are made from the same types of raw materials as are the standard models, however, and consequently care is taken in ordering materials to secure an ample supply so that no delay in fabricating such orders will result from a lack of materials. Likewise, in requisitioning parts which are used both in standard and special models, an extra supply to provide for special orders is provided. It is difficult to determine just how the amounts of these excess supplies are decided, it having been stated by the production manager, when this question was raised, that this was a matter of judgment and a question which he himself had to decide in each case on its individual merits.

No material or parts inventory records and no special production-planning or control department is maintained. The estimated production requirements, when determined at the beginning of the month, are broken down into shop orders in the office of the production manager; and these orders are transmitted to the foremen of the various departments with instructions for them to proceed with the manufacturing operations. The foremen have complete authority with respect to such operations and submit daily progress reports to the central office. As special orders are received, these are transmitted to the foremen, who work them into the regular schedule so that they can be gotten through the shop at the time delivery is called for; and in the case of rush orders, close check upon progress is maintained by the central office by means of a clerk who acts as an order-tracer.

This general plan has not worked well in practice, since one department is frequently required to wait upon other departments for orders in process, and also in some departments there has been a pronounced tendency to rush the month's schedule through in the early part of the month, thus tending to create still greater irregularity in operations. It has been found also that in spite of a close follow-up by the central office, customers have frequently had to wait for delivery in rush times on standard models while special orders were being worked on by the shops. In dull times, on the other hand, the inventory of certain standard models and standard component parts has been found to be much larger than could be justified by expected sales in the immediate future.

It is felt by each of the three owners that before the new line of products is added a complete revision of the present system should be made, and you are to assume that you have been called in to make an investigation and recommendations as to what should be done. You have found in your first visit to the plant that conditions are as stated herein and you have been asked to make a preliminary report to the owners and managers outlining your views as to what should be done to remedy the situation. The president has asked you to be as explicit in your recommendations as possible, in order that they may decide what shall be the nature of your assignment.

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QUESTIONS FOR CLASS DISCUSSION

1. The X Manufacturing Company manufactures a single standardized product continuously. This product is sold on blanket contracts to several large consumers who typically place their commitments for several months in advance.

The Y Company manufactures several types of machines of standard model, each of which is assembled from many different parts. All such parts are produced in the company's own shops. It is usually possible to forecast fairly accurately for several months in advance what sales will be. Because of improvements in design, parts of the various models are changed from time to time, but such changes invariably come about slowly and there is always a limited market for repair parts for former models. These repair parts must be supplied by this company because of service considerations, and a limited inventory of such goods is accordingly always kept on hand.

The Z Company manufactures machine tools and highly specialized factory equipment. Specifications and preliminary designs are usually supplied by the purchaser's own engineering department. Many such orders are placed for delivery at the earliest possible moment, and the time required to fill the order is always an important competitive factor in securing the business. Very few orders are ever repeated for the products originally supplied.

Each of these three plants employs approximately 2,500 men during normal times.

Compare the problems of budgeting production and planning operations in these three plants.

Assuming whatever additional information concerning the respective organizations you require, draw up in outline form the production-control procedures which you think should be provided in each instance.

2. Discuss the relation between production-planning operations and each of the following groups of activities:

a) The establishing of standards of performance
b) The designing of products
c) The budgeting of production operations
d) The collection of pay-roll data
e) The costing of production operations

3. Indicate the differences in the method of planning production operations you would expect to find under traditional or "rule-of-thumb" management in contrast with "scientific management."

4. One of the criticisms often made of a highly centralized production-planning department is that it is inclined to get out of touch and sympathy with the shops which actually perform the work; that the foreman who is in intimate touch with shop conditions is the logical man to assume responsibility for many of the activities which are often placed under the jurisdiction of a planning department.

How would you answer such a contention? Assuming that there may be real merit in it, how would you attempt to meet the situation?

5. Of what value are production-planning boards and charts as an adjunct of production-planning procedures, and under what conditions would you use them?

6. "One important function of the production-planning department is to collect data necessary for preparing progress reports concerning current production operations."

Why is such information necessary?

Outline a procedure by which the collection of such data could be accomplished.

If there were no production-planning department, how might such data be compiled?

7. "A production-planning department assumes responsibility for many activities for which shop foremen were formerly held responsible."

Specifically, what activities?

Are there any planning activities for which, in your opinion, the foreman might well be held responsible even where a centralized production-planning department has been provided?

Be explicit and give reasons in support of your views.

8. Have other departments besides the production-planning department tended to encroach upon the sphere of the old-time foreman? Cite concrete instances.

9. Are you able to detect any "family resemblances" between the modern production-planning department and Frederick Taylor's plan of functional foremanship?

10. In view of certain modern tendencies with respect to production methods, such as standardization and mass production, do you think that the need for a production-planning department will tend to become more or less important in the future?

EXERCISE XV

Conduct a field investigation concerning production-planning methods in some manufacturing organization and present a report outlining their procedures. Make any concrete suggestions and criticisms of their methods which you think, if adopted, might lead to improvement.

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Case and problem materials on the subject of this chapter may be found in E. H. Schell and H. H. Thurlby, *Problems in Industrial Management* (Shaw, 1927), pp. 293–342.

QUESTIONS FOR CLASS DISCUSSION

1. Discuss the problem of incentives in the production sphere, contrasting and comparing it with the problem as presented in other departments.

2. List as many different kinds of incentives as you can, indicating what you believe to be their relative importance as managerial devices.

3. "All incentives are based upon one or the other of two basic concepts: (1) fear of punishment, and (2) hope of reward."

Discuss the relative incentive values of these two types of stimula, citing concrete examples of their application.

Do you agree with the foregoing statement? Defend your views.

4. The various tests of incentive value as applied to wage systems suggested in this chapter were as follows:

a) Direct relation to the workman's personal welfare
b) Reward in proportion to the workman's individual efforts
c) Immediateness of reward
d) Progressively increasing reward
e) Simplicity of design
f) Impartiality and fairness in application
g) Permanence of agreement
h) Non-competitive rewards

Discuss the relative importance of these various tests.

Would you add to or subtract from the list?

Make a list of twenty different wage systems you have found in your readings, and apply these tests to each.

5. How do you account for the fact that wage-incentive systems have occupied so important a place in the literature of the scientific management movement?

6. Do you regard "profit-sharing" as an incentive plan? Why or why not?

7. "The surrender by the employer of any portion of his legitimate profits without assurance of an equivalent return from those on whom he bestows it is wrong in principle." Discuss and criticize this quotation.

8. Discuss and illustrate the difference between a "piece-rate" and a "gain-sharing" plan.

9. "The difficulties of the piece-work plan spring from the fact that when the piece rate is once set, an increase of effort by the worker redounds to his own benefit alone, the employer having no sharing in the saving of time, and cutting the piece rate accordingly becomes the only method of reducing cost." Discuss.

10. Admitting that rate cutting is or may be a seriously disturbing factor in the relations of management and labor, how would you suggest coping with the problem?

11. "If the premium (in the form of increased wages for increased effort) is too high, the employer simply pays more than it would be necessary for him to pay." Discuss. How is the employer to know when "the premium is too high"?

12. Some of the early critics of incentive plans insisted that workmen should be expected to share in losses if they are to be permitted to share in profits. Discuss.

13. In discussing Towne's gain-sharing plan, one man pointed out that such schemes "should be applied only for the purpose of increasing efficiency and not for obtaining lower rates on labor than the current market commands." What about it? Do you think there is any possibility of obtaining lower rates than the current labor market commands by introducing any specific system? If not, why? If so, how?

14. William Kent, who in 1886 described what he called "a problem in profit-sharing," suggested the following plan:

a) The share of workmen in excess of the stipulated wage should be calculated not on net profits but on the savings in the manufacturing department.
b) Standards should be set at the beginning of the year specifying the maximum allowable cost for the year.
c) Daily wages should be paid.
d) At the end of the year men should be paid a certain agreed-upon percentage of savings made in their department after deducting any savings traceable to the introduction of machinery or added expenditures of capital.

Discuss and criticize this plan.

Do you think it would be of any value under modern conditions? Why or why not?

15. What is the significance of the distinction "scientific" versus "non-scientific," as sometimes referred to in speaking of incentive systems?

16. Outline briefly what, in your opinion, appear to have been the chief contributions to our thinking on wage incentives of each of the following:

a) Henry Towne
b) F. A. Halsey
c) F. W. Taylor
d) H. L. Gantt
e) Harrington Emerson
f) C. E. Bedaux

17. In recent writings on wages such phrases as the following are frequently encountered:

a) "wages of contentment"
b) "satisfactory wage"
c) "just wage"
d) "equitable wage"
e) "minimum standard of living wage"
f) "savings wage"
g) "cultural wage"

Discuss the meaning and significance of these various phrases. Have they any relation to the general problem of wage incentives?

18. What factors in modern industry have, in your opinion, been responsible for the growing importance of group-incentive plans?

19. Do you think wage incentive plans will become more or less important in the industry of the future? Consider carefully.

20. State the conditions which you think are prerequisites for successful use of the straight day wage.

21. What specific factors besides output may properly be dealt with by an incentive system?

Cite concrete illustrations showing just how each of these other factors you have mentioned may be dealt with by such a system.

22. Contrast and compare the problem of providing proper incentives for each of the following groups of workers:

a) Factory direct workers
b) Factory indirect workers
c) Inspectors
d) Designers and research men
e) Foremen
f) Routine office workers
g) Salesmen
h) Departmental executives
i) General executives

23. Balderston arrives at the following conclusion concerning "group incentives":

> It captures the interest and enthusiasm of the team and, like other incentives, it appeals to those who believe in a philosophy of leadership as contrasted with "driving." Perhaps the greatest significance of group incentives is that they emphasize team work and co-operative effort rather than individual self-interest.

Assuming the correctness of this conclusion, do you think that group incentives are likely to become more widely used in the future than in the past? Is team work likely to become more important than formerly?

In your opinion is the individual incentive likely to prove deficient in this respect? Just how does the group incentive contribute in greater degree to the development of team work, if it does so?

Do you see any disadvantages of the group-incentive as compared to the individual-incentive plan?

EXERCISE XVI

The Mogul Tractor Company, which manufactures farm tractors and harvesting combine machinery, has a plant employing approximately 3,100 workers. The various processing departments of the plant, together with the approximate numbers of employees in each, are as shown on the next page.

At the present time approximately three-fourths of the direct workers are on straight piece rate. The remainder and the indirect workers are on day rate.

The product is all standardized, and no special work is carried on in the plant. Finished parts are manufactured on requisitions from the stores department, which maintains a stores control system designed on the "maximum and minimum" principle. These parts, when completed, are placed in stores and are issued to the assembling department as needed. The latter department assembles the product only as sales or shipping orders are received.

Piece rates are determined on the basis of past experience and trial runs, under the supervision of foremen. The rates are set at the point which it is thought will enable a reasonably efficient workman to earn the current market rate for his grade of skill.

	Direct Workers	Indirect Workers
Foundry	300	200
Forge shop	200	200
Sheet-metal shop	75	25
Machine shops	900	450
Assembly department	200	100
Inspection forces	....	125
General maintenance: tools, stores, etc.	....	250
General supervisory forces	....	75
Total	1,675	1,425

The plan has not been entirely satisfactory. "Soft" jobs have developed at many points, and the workmen have been somewhat dissatisfied on account of alleged favoritism on the part of foremen. A somewhat cursory investigation of complaints by the production manager has led him to believe that many inequalities have been permitted to creep into the rate schedule. As a whole, the wages paid do not exceed those paid in competitors' plants, but he strongly feels that unit labor costs are in many instances somewhat higher than those of competitors on similar grades of work.

The management for sometime has been considering the question as to whether a bonus system of some sort would not give better results, as a number of industrial engineers have contended. One of their competitors has, it is known, installed a system with a guaranteed rate of day pay and a "savings-sharing" provision with which, from all reports, the workers are well satisfied.

You have been consulted in the matter as one having no specific plan for sale, and have been asked to draw up a report in which you will indicate the various general types of plan which might be adapted to their situation and to outline the important points requiring consideration if such an installation is to be undertaken. The management has stated that it is willing to undertake a thorough reorganization of its wage-payment methods if it becomes convinced that the present methods are fundamentally at fault.

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Additional case and problem materials on the subject of this chapter may be found in E. H. Schell and H. H. Thurlby, *Problems in Industrial Management* (Shaw, 1927), pp. 440–46.

QUESTIONS FOR CLASS DISCUSSION

1. Someone has said that "all science is measurement." Admitting that, as suggested in this quotation, the two concepts of science and measurement are inseparable, consider the significance of measurement in relation to the science of management.

Wherein do the business manager's problems of measurement differ from those of the engineer or natural scientist?

Are the activities with which managers deal susceptible of measurement? Discuss in terms of concrete cases.

2. Discuss the problem of measuring performance in each of the following spheres:

a) A machine operator
b) An indirect factory worker such as a janitor or a night watchman
c) A departmental foreman
d) The inspection department
e) A designer or industrial research worker
f) The production-planning department
g) A salesman
h) The sales department
i) The accounting department
j) The purchasing department
k) The production manager
l) The shipping department
m) The traffic department

n) The personnel department
o) The financial department
p) The president or general manager

3. Draw up a list of specific measuring devices which are applicable to production activities. Indicate just what each may reasonably be expected to measure and the degree to which, in your opinion, they actually do provide a measure of the thing or activity they are supposed to measure.

4. How do you account for the fact that cost accounting has usually been regarded as peculiarly related to production activities?

Do you think this usual practical limitation of the cost accountant's sphere is necessary or desirable? Defend your views.

5. Indicate just how you would attack the problem of measurement presented in determining each of the following:

a) The mechanical efficiency of a machine
b) A "fair day's work"
c) The basic wage to be offered for a given factory task and the wage differentials between tasks
d) The relative merits of a given wage-incentive system
e) The relative merits of two different methods of performing a given task
f) The relative merits of two possible locations for a new factory
g) The relative merits of two different plans of organizing the production department
h) The relative merits of two different plans of layout for a factory department
i) The justifications of a proposed company pension system for superannuated factory workers

6. "Reports on the cost of not producing are quite as important as reports on the cost of production." Give concrete content of this statement.

7. What are "differential costs"? Of what significance, if any, are they to the production manager?

8. "The real task of the cost accountant is becoming more and more the explaining of cost variations." Explain.

9. "The purpose of the accounting records is to show what has happened, not what might have happened; therefore all of the expenses incurred during a period should be charged to the cost of goods produced during that period." State your opinions concerning the foregoing contention.

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